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DESIGN, DEVELOPMENT, AND TESTING OF
TIRES FOR 16 TON GOER VEHICLES

FINAL REPORT

CONTRACT NO. DA-33-019-ORD-3478
(Including Modification 1 - 7)

THE FIRESTONE TIRE & RUBBER COMPANY
AKRON, OHIO

This project was performed under the technical
supervision of Research & Engineering Directorate,
Army Tank-Automotive Command.

Cleveland Ordnance District Office
Ordnance Project No. TW-510
D/A Project No. 546-09-036

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November, 1963

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Abstract

AD _____ Accession _____
Firestone Tire and Rubber Co., Akron, Ohio
Design and Testing of 29.5-25 tires for
16 ton Goer Vehicle - T. J. Lonson, E. S. Sites
December, 1963 - pp - illus - tables

Contract No. DA-33-019-ORD-3478
D/A Project No. 546-09-036
Unclassified Report

Earthmoving tires were specifically developed for use on the Goer vehicle. This development work included the design of various tread configurations and use of maximum feasible synthetic content. Tires were produced in three different tread designs, and two different levels of synthetic content. These tires were then tested for running temperature, traction, and mobility. Durability tests of 40% highway, 40% secondary roads, and 20% cross country were conducted. These tests showed that tires could be produced to provide at least 15,000 miles without any premature failures for this type of service.

OBJECT

The object of the original contract dated 30 September 1960 was to design and develop 29.5-25 16 ply rating tubeless tires to provide optimum performance when used on the Goer vehicle. It was also desired to attain these goals while using the maximum feasible synthetic content.

Subsequent modifications (1-7) from June, 1961 through January, 1963 called for:

1. Non-destructive drum testing.
2. Temperature testing in continuous highway service.
3. Traction testing in various soils.
4. Durability testing on paved (40%) and secondary (40%) roads and off-highway terrain (20%).

Conclusions:

1. We found that it was possible to produce tires more suited to the requirements of the Goer vehicle than any commercially available tire. The major areas of improvement includes the capacity for continuous highway operation and improved performance in mud. The three designs developed are shown in figures 1-4.

Figure 1 - Super Ground Grip Goer

Figure 2 - Super Ground Grip Goer (Grooved)

Figure 3 - ND-CC Goer

2. Maximum synthetic content of the 29.5-25 SGG Goer was found to be 50% of the polymer used. The maximum synthetic content was determined by an evaluation of compound properties considering separation resistance and wear, cut, chip and tear resistance, as determined through the specific tests performed during the term of this contract and its modifications. However, certain inherent deficiencies from increasing synthetic (relative to natural rubber which is being replaced) in larger Off-The-Road type tires, should be recognized.

These are:

A. Higher Heat Build-Up

To use synthetic in the tread of the tire, it was found necessary to incorporate a cooler-running, high-natural-rubber-content compound in the tread base under an all-synthetic tread cap compound, in order to lower the tire temperature in the critical separation area on top of the tire carcass.

B. Poor Crack or Cut Initiation and Growth

This deficiency manifested itself quite markedly during the durability testing. As a result of these tests, compound modifications were made in the all-synthetic tread cap stock to improve upon this property for future Goer tires.

C. Lower Resistance to Chip and Tear

Although the all-synthetic tread cap has been compounded to obtain the maximum cut, chip and tear resistance, without sacrificing other properties, there is an inherent lower resistance relative to natural rubber, for Off-The-Road type service, which compromises the overall performance of the tire. The exterior compounds of the tire (i.e. the tread and sidewall) have adequate protection against atmospheric deterioration and good low temperature

Firestone

Super Ground Grip Goer

Directional

Figure 1



Firestone

**Super Ground Grip Goer
(with grooves)**

Directional

Figure 2

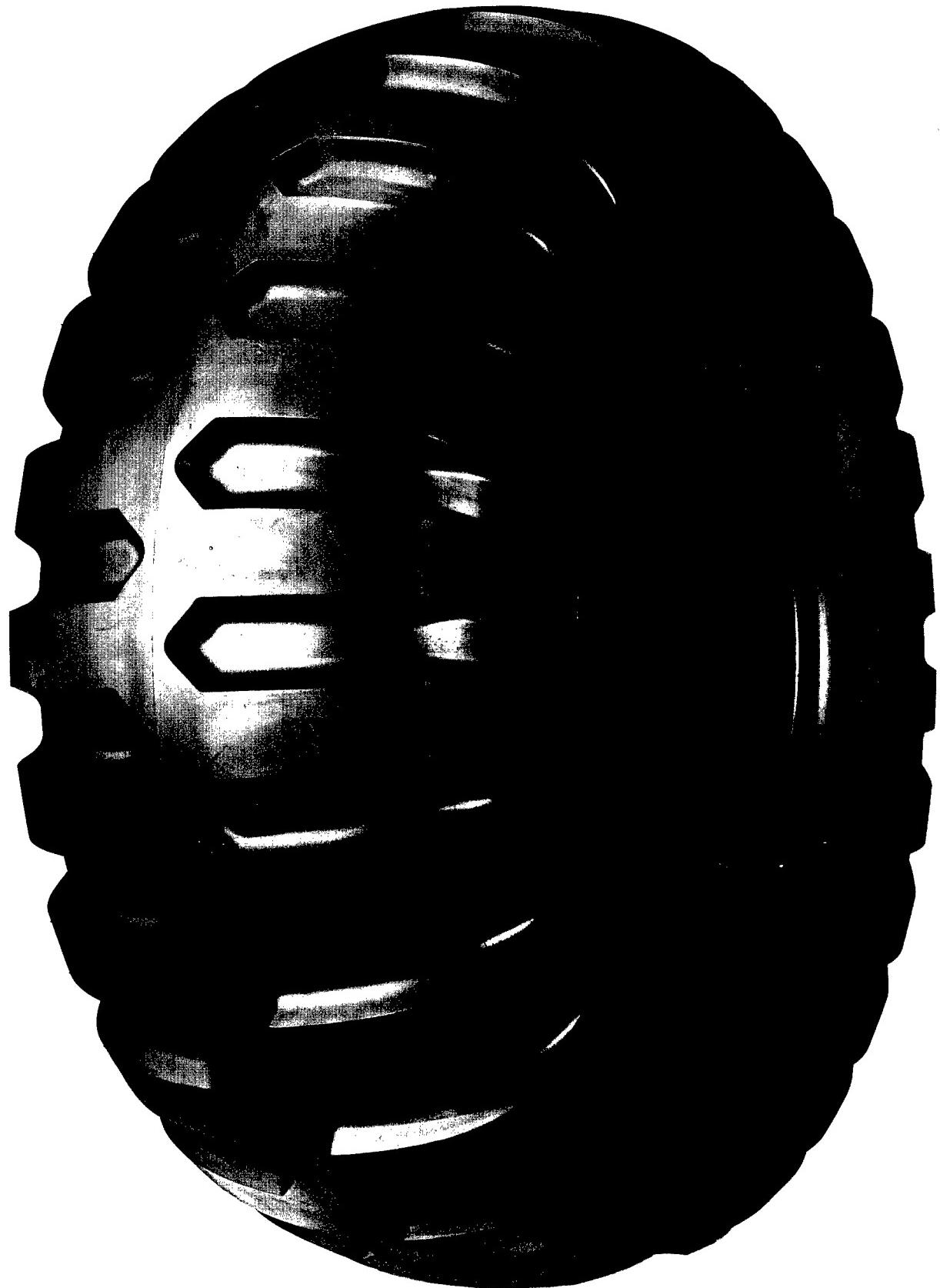


Firestone

ND-CC Goer

Non-directional

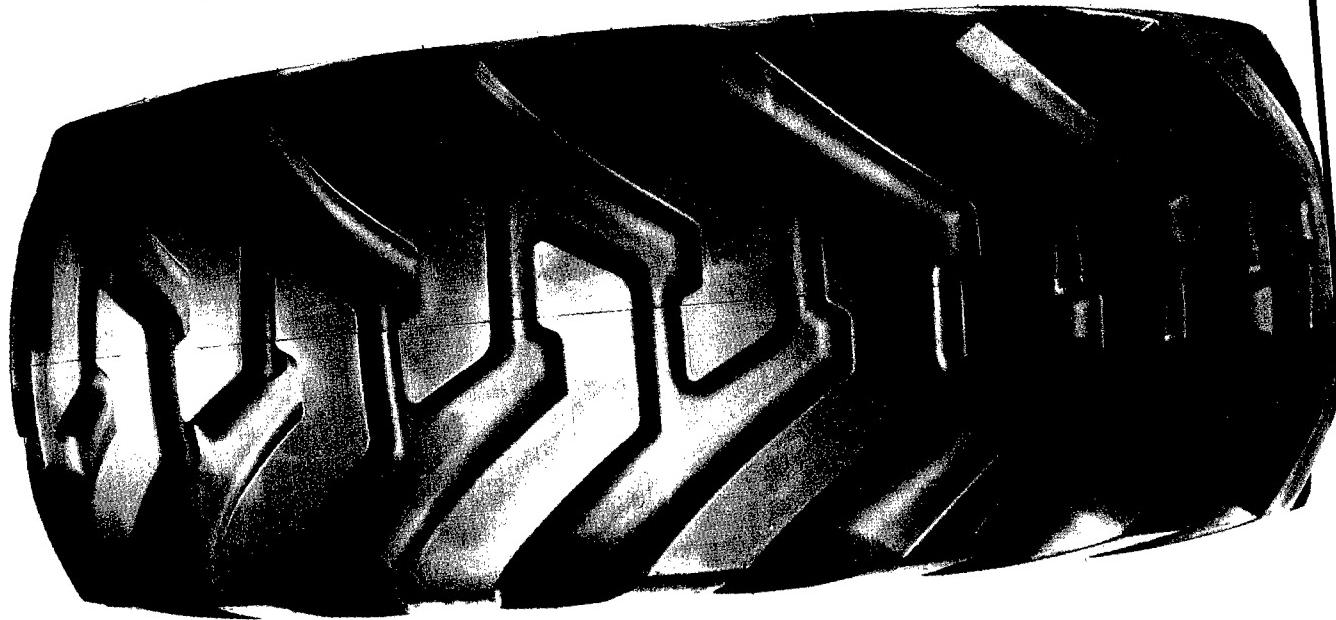
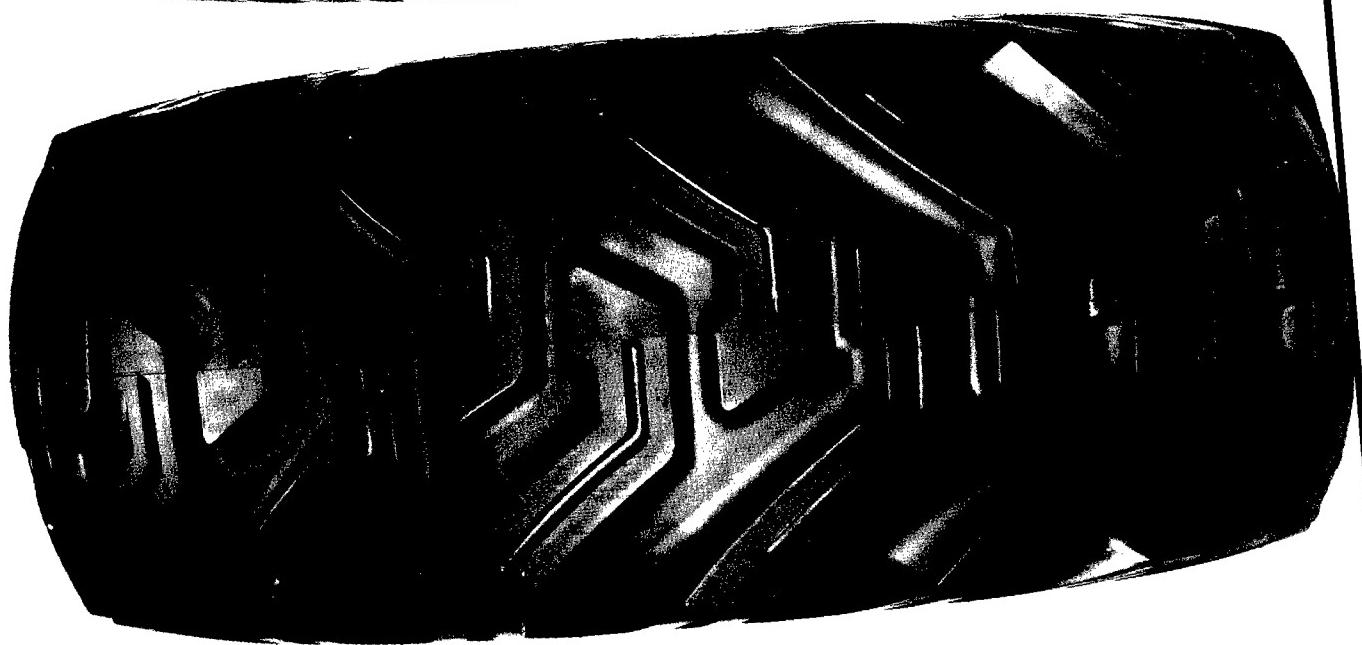
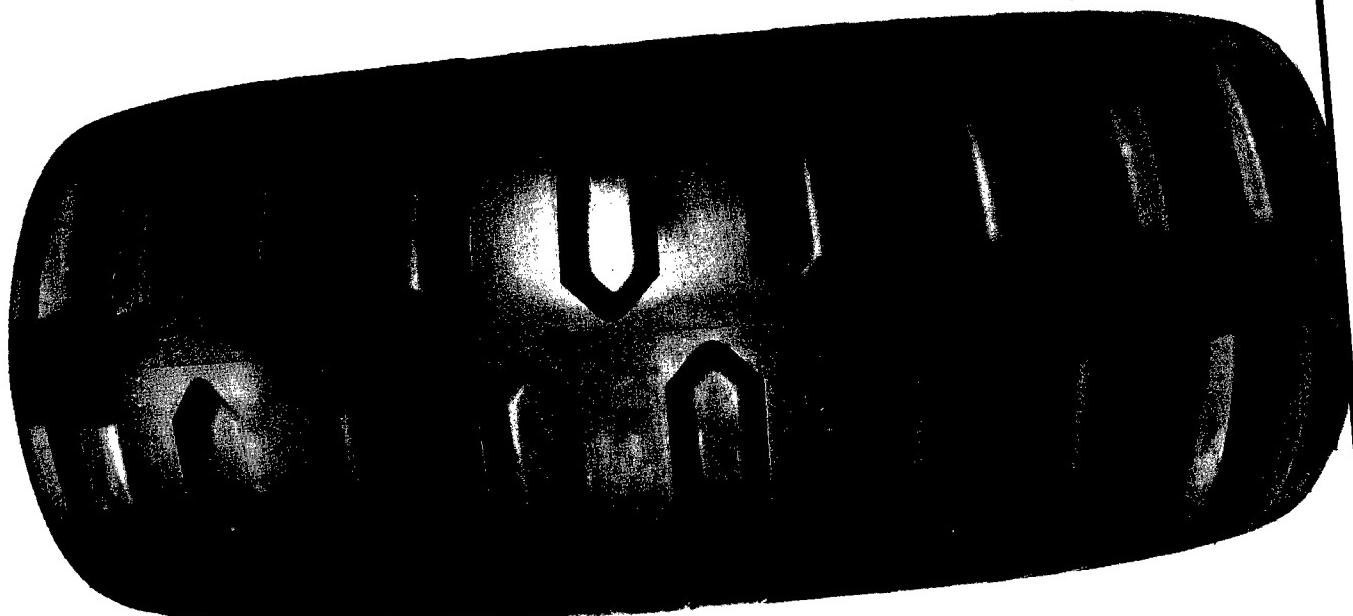
Figure 3



Head-on view of the three test designs
From left to right-

Super Ground Grip Goer
Super Ground Grip Goer (with grooves)
ND-CC Goer

Figure 4.



flexibility as a result of the particular blend of synthetic polymers used.

Use of the protective coatings described under Tire Compounding markedly enhances the tires' exterior compounds' resistance to atmospheric deterioration.

3. Of the three designs developed for this contract, the best design for optimum performance, as determined by these tests, was the Super Ground Grip Goer tire with the grooved tread bars. This was the only tire of the three which would operate at a sufficiently low temperature to allow use of the maximum synthetic rubber construction and still permit continuous highway operation. This design, with or without the tread grooves, is approximately three times as effective in deep mud as the ND-CC Goer design. The ND-CC tire was approximately 10 to 15% more effective for drawbar pull on non-compressible surfaces and compressible soil. There was little difference in the sand performance of any of these designs. Our selection of the grooved Super Ground Grip Goer tire as the optimum was based on the premise that the prime requirement of these tires was the ability to operate continuously in highway service and provide maximum performance in mud.
4. Shown below is a table which summarizes the information obtained from the durability phase of the testing. The significant factors are that no tires were removed due to any type of premature failure. Also, the tires with the synthetic tread had a wear rating double that of the natural rubber tires.

TABLE - DURABILITY TEST SUMMARY

TYPE	SGG GOER (GROOVED)	SGG GOER (GROOVED)	ND-CC GOER
Compounding	Natural Rubber	Synthetic Rubber	Natural Rubber
Average Test Miles Per Tire Sample	10,022	15,040	7,509
Reason for Removal	Worn Smooth	Worn Smooth	Test Terminated
Durability Rating	100	150	Not Available
Tread Wear, Average Miles/mil. (1)	6.1	12.2	16.3
Tread Wear Rating	100	200	267

(1) See pp. 19-20 of Final Report, Durability Testing - Summary of Tire Tread Wear

It can be concluded from this testing that the Super Ground Grip Goer (grooved) tire with the natural rubber construction will not provide the desired 15,000 mile durability; however, through use of a synthetic construction, this level can be achieved. The ND-CC Goer design should provide approximately 20 to 25,000 miles with the natural rubber construction used, and could possibly double this figure by using the same synthetic compounds used in this test. It must be remembered that we are limited by the operating temperatures also.

Recommendations

1. Since no one design tested was clearly superior in all of the categories evaluated, it would seem that there is probably some design that would provide better overall performance than either of the three designs tested. It is our recommendation that additional testing be conducted to evaluate other design variations that would improve the mobility of the Goer vehicle.
2. This contract was limited to a tread design and compounding evaluation. It would also be beneficial to conduct tests in an attempt to evaluate the effects of various types of carcass constructions.
3. Use compound modifications to the all-synthetic tread cap compound referred to under conclusion #2 and under Tire Compounding, section B-1. These modifications were incorporated into the tires being fabricated for the European Troop Tests to be conducted in the spring of 1964.
4. Use tire protective Coating A referred to under Tire Compounding, section A-5. This coating has been used on all Goer tires manufactured by Firestone.
5. In view of the promising performance of the high-percentage-synthetic compounds in these tires, in service where natural rubber is normally used, continued compounding studies should be conducted to improve upon the overall performance characteristics of the high-synthetic-bearing compounds.

Background

Prior to this development contract, special tires were produced in existing commercial molds and supplied for use on the first four Goer vehicles. Design features of these tires were aimed primarily at maximum traction and continuous highway operation.

These tires performed fairly well, but a need was recognized for tires designed specifically for Goer vehicle-type service.

Subsequently, this contract called for production of four tires of each of three different designs. In addition, tires were to be produced with the maximum feasible synthetic content. In order to test these various characteristics, the following five tire specifications were issued and the corresponding tires produced:

<u>Serial</u>	<u>Type</u>	<u>No. Tires</u>	<u>% Synthetic</u>
K12500	SGG Goer	2	11%
K12600	SGG Goer	2	52%
K12700	SGG Goer with grooves	4	13%
K12800	ND-CC Goer	2	14%
K12900	ND-CC Goer	2	56%

Modification 1 dated 22 June 1961 called for one of each of these tires to be tested on an indoor laboratory drum to provide a temperature comparison.

Modification 3 dated 20 September added on-vehicle testing which would include an evaluation of these tires for continuous highway operation, mud, sand, drawbar pull, slopes, and maneuverability. These tests were subcontracted to Le-Tourneau-Westinghouse with ATAC approval. They conducted the highway temperature comparison and the mud tests but the drawbar pull tests in sand, non-compressible surface, and compressible soil were subcontracted by them to Nevada Automotive Test Center, Carson City, Nevada.

Modification No. 7 added a 20,000 mile durability test and twelve additional tires were supplied. Six of these were control tires in the Super Ground Grip Goer (with grooves) design with standard earthmover tire construction and compounding (natural rubber) features. The remaining six tires were the same except that the maximum possible synthetic rubber content was used.

In addition five tires in the ND-CC Goer design were purchased under contract number DA-20-089-ORD-40018. These tires were used as replacements for the durability test. Four of these tires attained 7500 miles before the 20,000 mile test limit was reached.

Mold Design and Tire Construction Development

The design of the tires for the 16 ton Goer vehicle requires consideration of the following criteria:

1. Gross Vehicle Weight - 64,000 Lbs.
4 Tires
58% of load on front axle
42% of load on rear axle
2. Speed - Maximum over 30 MPH
Cruise at 20 MPH
Water at 4 MPH
3. Roadability - Capable of long sustained hauls.
4. Traction - Maximum in mud.
5. Flotation - Good in all soils (mud and sand).
6. Minimum vehicle.
Ground Clearance - 30"
7. Ozone Resistance - Equivalent of standard military specification requirements.
8. Compounding - Maximum feasible synthetic content.
9. Durability - 25,000 miles.

From the above data, the 29.5-25 size was selected as the optimum tire for use on this vehicle. This will provide the load carrying capacity and ground clearance required, and this wide base profile will provide maximum flotation and traction.

After the size selection was finalized, it was necessary to arrive at the best possible tread configurations. It was originally decided to bring in one tire mold with three separate tread rings; however, upon consideration of factory production engineers, it was decided to fabricate two unicast molds rather than one. Although this increased the cost over the original estimate, the advantages provided both the contractor and the customer decisively outweighed the additional cost to the contractor.

The three tread designs selected were:

1. Super Ground Grip Goer (maximum traction) See figure 1
2. Super Ground Grip Goer with grooves (modified maximum traction). See figure 2.
3. ND-CC Goer. See figure 3

The Super Ground Grip Goer design was similar to our own commercially proven Super Ground Grip WB tire. The purpose of the tread grooves in the modified tire was to reduce the tire operating temperature. Prior experience indicated that this would reduce tire operating temperatures by approximately 15°F.

Design dimensions for the ND-CC Goer were based on Tire and Rim Association limits and design criteria in MIL-T-12459A for cross country type tires.

Shown below is an evaluation of the performance characteristics which we felt could be expected from these three designs:

	<u>Super Ground Grip Goer</u>	<u>Super Ground Grip Goer (with Grooves)</u>	<u>ND-CC Goer</u>
Directional	Yes	Yes	No
Mud Traction	Excellent	Excellent	Good
Sand	Good	Good	Good
Highway Roadability	Fair	Fair	Fair
High Speed	Good	Excellent	Good
Continuous Operation			
Wear Resistance	Good	Good	Good
Cut Resistance	Fair	Fair	Fair

In order to carry the required load and yet have the lightest possible construction, a 16 ply rating construction was chosen as the optimum. The load rating for this tire is 17,190 pounds at 25 psi inflation for intermittent operation and 14,520 pounds at 30 psi for continuous highway operation. The weight of these tires is approximately 800 pounds.

The carcass construction utilized 840/2 nylon with a tensile of 30 pounds per cord. These twelve tires were of twin bead construction, 14 actual plies, and two tread plies. They also had an under base of .45". All other features were standard production items with the exception of the compounding.

TIRE COMPOUNDING

A. ORIGINAL CONTRACT

1. BASIC REQUIREMENTS FOR GOER TIRE COMPOUNDS

1. COMPOUND STOCK WITH MAXIMUM SYNTHETIC CONTENT
2. COMPOUND STOCKS FOR PROTECTION AGAINST ATMOSPHERIC
DETERIORATION
3. COMPOUND PROTECTIVE COATING TO COMPARE WITH (2)
4. COMPOUND: BEST COMPROMISE BETWEEN COOL RUNNING TIRE AND
CUT, CHIP AND WEAR RESISTANT TREAD AND SIDEWALL

2. COMPOUNDS SELECTED FOR FABRICATION OF TIRES

TIRE IDENTIFICATION

29.5-25 16 PLY TUBELESS

	<u>SERIAL IDENTIFICATION</u>	<u>COMPOUND LINE-UP</u>	<u>% OF POLYMER AS SYNTHETIC</u>	<u>NO. OF TIRES</u>
SUPER GROUND GRIP GOER MAXIMUM TRACTION DESIGN	K12500	I	11	2
	K12600	II	52	2
SUPER GROUND GRIP GOER MODIFIED MAXIMUM TRACTION DESIGN	K12700	I	13	4
ND-CC GOER DESIGN	K12800	I	14	2
	K12900	III	56	2

2. COMPOUNDS SELECTED FOR FABRICATION OF TIRES

	COMPOUND DESCRIPTION		
	<u>LINE UP I</u>	<u>LINE UP II</u>	<u>LINE UP III</u>
Tire Serial Identification	K12500, K12700, K12800	K12600	K12900
Tread	NR	Isoprene	Oil Extended FR-S
Sidewall	$\frac{1}{2}$ Neoprene- $\frac{1}{2}$ NR	$\frac{1}{2}$ Isoprene- $\frac{1}{2}$ NR	Oil Extended FR-S
Outer Body	NR		$\frac{1}{4}$ Isoprene- $\frac{3}{4}$ NR
Inner Body	$\frac{1}{4}$ Diene - 3/4 NR	Same as Line Up I	Same as Line Up I
Innerliner	7/10 Chlorobutyl-3/10 NR	" " " "	" " " "
Bead Insulation	FRS	" " " "	" " " "
Other Bead Compounds	NR	" " " "	" " " "

3. COMPOUND DESIGN

COMPOUND LINE UP I

Compound Line Up I with 11 to 14% of the polymer as synthetic (depending on weight distribution of tire components) is the least deviation from standard Off-The-Road Tire Compounding.

This Line Up features an all natural rubber tread with superior cut and tear resistance. The tread is specially compounded for cool running and resistance to atmospheric deterioration.

The sidewall is compounded from a polymer blend of 50% Neoprene and 50% natural rubber, and is extremely resistant to atmospheric deterioration.

The outer body is compounded from all natural rubber. It is cool running and furnishes maximum tear and heat resistance.

25% of the polymer as Diene and 75% natural rubber is the feature of the inner body. It is cool running and heat resistant.

The innerliner is compounded with 70% of the polymer as chlorobutyl and 30% natural rubber. Excellent heat resistance and impermeability to air are its features. One-half as much air is transmitted at 176°F and 75 psi through this type innerliner than through an all natural rubber innerliner.

COMPOUND LINE UP II

Compound Line Up II with 52% of the polymer as synthetic is a greater departure from standard compounding. Its tread polymer is 100% Isoprene specially compounded for best compromise between cool running and resistance to wear, tear and atmospheric deterioration.

The sidewall, compounded from 50% Isoprene and 50% natural rubber, is tear, cut and atmospheric deterioration resistant.

The same compound features as Line Up I are used in the remainder of the tire.

COMPOUND LINE UP III

Compound Line Up III, with 56% of the polymer as synthetic, features tread and sidewall compounds with all of the polymer as oil extended FRS, specially compounded for resistance to atmospheric deterioration.

The tread and sidewall are also compounded for cool running and cut and tear resistance.

Isoprene as 25% and natural rubber as 75% of the polymer is the feature

of the outer body. The outer body is compounded for cool running, and heat and tear resistance.

The remaining compounds are the same as Line Up II and III.

4. COMPOUND PROPERTIES

TREAD

Compound Line Up:	I	II	III
Tire Identification Serial:	K12500, K12700 K12800	K12600	K12900
Formulation:	100 NR	100 Isoprene	131 FR-S 123
<u>Normal (70°F) Stress-Strain</u>			
Tensile, psi	4175	3025	3075
300% Modulus, psi	1750	1625	825
Elongation, %	540	480	675
<u>Tensile @ 275°F</u>			
Tensile, psi	1100	625	700
Elongation, %	320	210	340
<u>Normal (70°F) Tensile After 2 Days @ 212°F</u>			
Tensile, psi	2250	1275	2675
Elongation, %	250	185	465
<u>Firestone Flexometer</u>			
Running Temp., °F	226	240	275
Deflection, %	15.3	16.7	20.7
Shore "A" Hardness	64	63	62
<u>Ring Tear</u>			
Normal-70°F, lb/in	800	500	525
-212°F, lb/in	300	200	275
<u>Brittle Point</u>			
ASTM D746-57T, °F	-63	-60	-45

4. COMPOUND PROPERTIES

SIDEWALL

Compound Line Up:	I	II	III
Tire Identification Serial:	K12500, K12700, K12800	K12600	K12900
Formulation:	50 NR 50 Neoprene	50 NR 50 Isoprene	131 FR-S 123

Normal (70°F) Stress-Strain

Tensile, psi	3175	3725	3000
300% Modulus, psi	900	975	500
Elongation, %	640	635	765

Tensile @ 275°F.

Tensile, psi	700	700	400
Elongation, %	350	360	270

Normal (70°F) Tensile After 2 Days @ 212°F

Tensile, psi	1975	1025	2575
Elongation, %	405	265	570

Firestone Flexometer

Running Temp., °F	203	201	246
Deflection, %	26.7	20.0	24.7
Shore "A" Hardness	50	57	57

Ring Tear

Normal-70°F, 1b/in -212°F, 1b/in	325 100	575 225	400 175
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Brittle Point

ASTM D746-57T, °F	-71	-53	-45
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4. COMPOUND PROPERTIES

BODY

Compound Line Up:	I	II	III	I,II,III
Formulation:	<u>Outer Body</u>	<u>Outer Body</u>	<u>Outer Body</u>	<u>Inner Body</u>
	100 NR	100 NR	75 NR	75 NR
			25 Isoprene	25 Diene
<u>Normal (70°F) Stress-Strain</u>				
Tensile, psi	4125	4100	3975	2900
300% Modulus, psi	1200	925	875	800
Elongation, %	600	670	685	580
<u>Tensile @ 275°F.</u>				
Tensile, psi	1250	1250	1025	475
Elongation, %	520	630	540	220
<u>Normal (70°F) Tensile After 2 Days @ 212°F</u>				
Tensile, psi	2050	1675	1925	1525
Elongation, %	375	390	425	405
<u>Firestone Flexometer</u>				
Running Temp., °F	189	184	188	132
Deflection, %	23.3	24.7	26.0	20.7
Shore "A" Hardness	52	51	49	54
<u>Ring Tear</u>				
Normal-70°F, 1b/in	550	850	550	200
-212°F, 1b/in	300	350	325	125
<u>Brittle Point</u>				
ASTM D746-57T, °F	-69	-67	-63	-66

4. COMPOUND PROPERTIES

REMAINDER OF COMPOUNDS

Innerliner, Bead Insulation, Bead Cover, Bead Filler, Chafer and Abrasion Gum Strip compounds are all standard Firestone compounds.

5. PROTECTION FROM ATMOSPHERIC DETERIORATION

COMPOUND PROTECTION

Tread and sidewall compounds feature standard Firestone Off-The-Road antiozonants for maximum resistance to atmospheric deterioration.

The oil extended FR-S tread and sidewall, and the Neoprene/natural rubber sidewall are superior to the Standard Military Control for accelerated weathering in the Firestone Weatherometer.

The natural rubber and Isoprene treads, and the natural rubber/Isoprene sidewall, while somewhat inferior to the Standard Military Control for accelerated conditions, are expected to be well protected for normal operations.

Comparisons of tread and sidewall compounds and the Standard Military Control were made in the Firestone Weatherometer under the following conditions:

1. 60 parts per 100 million of Ozone - 40 hrs. exposure-static - 100°F. - pre-aged 3 days at 158°F - 12½% elongation
2. Same as above except dynamic (10 min. flex - 50 min. static per hour) and strips not pre-aged
3. Same as (1) above except exposure at 40°F.

Photographs of results are on the following pages.

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER ~
60 PPHM OZONE, 40 HOURS, STATIC, 100°F
AGED 3 DAYS AT 158°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 40°F
AGED 3 DAYS AT 158°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 100°F
AGED 3 DAYS AT 158°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 40°F

AGED 3 DAYS AT 158°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II
TIRE SERIALS K12600

COMPOUND LINE UP III
TIRE SERIALS K12900

6. PROTECTION FROM ATMOSPHERIC DETERIORATION

PROTECTIVE COATINGS

From previous experience and studies during the period of this contract, the following two coatings were selected as the most practical.

A. Firestone protective coating based on N, N'-dioctyl-p-phenylene diamine.

B. Firestone protective coating based on Hypalon.

Coating A protects against atmospheric deterioration by depositing a layer of antiozonant which is absorbed into the surface of the tire.

Coating B protects against atmospheric deterioration by depositing a tough, clinging, elastic, protective film on the surface of the tire.

These coatings are very effective, but have the deficiency typical of coatings in that severe weathering occurs where the film is broken or not continuous, as shown in the photographs.

Comparisons of accelerated weathering, in the Firestone Weatherometer, of these coatings on the natural rubber tread (Line Up I), the Isoprene tread (Line Up II), and the natural rubber/Isoprene sidewall (Line Up II) are shown in the attached photographs.

Test conditions are the same as those described under Compound Protection.

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC 100°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 100°F
AGED 3 DAYS AT 158°F
TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B
TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

FIRESTONE WEATHERCIMETER

60 PPHM OZONE, 40 HOURS, STATIC, 40°F

AGED 3 DAYS AT 158°F

TREAD COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP I - COATING A

TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP I - COATING B

TIRE SERIALS K12500, K12700, K12800

COMPOUND LINE UP II - COATING A

TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B

TIRE SERIALS K12600

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, DYNAMIC, 100°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER
60 PPHM OZONE, 40 HOURS, STATIC, 100°F
AGED 3 DAYS AT 158°F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

FIRESTONE WEATHEROMETER
60 PPHM OZONE; 40 HOURS, STATIC, 40° F
AGED 3 DAYS AT 158° F
SIDEWALL COMPOUNDS

STANDARD MILITARY CONTROL

COMPOUND LINE UP II - COATING A
TIRE SERIALS K12600

COMPOUND LINE UP II - COATING B
TIRE SERIALS K12600

B. DURABILITY TESTS

1. COMPOUND MODIFICATIONS

Prior to fabricating the 29.5-25, 16 ply SGG GOER tires for the Durability Tests, a review of the original three compound line ups' performance pointed out the need for some reconsiderations of the compound design. In order to improve the tires' durability characteristics from an overall compromise between cool running and cut, chip and wear resistance, a number of modifications were made in the compounding design. An overall compromise, utilizing the maximum synthetic content felt to be permissible, was chosen for one set of tires (K25500 Serial Identification), to be tested against control tires (K25300 Serial Identification) using standard Firestone Off-The-Road compounds (approximately all natural rubber).

The final selection of compounds featured a three-piece tread construction (details below) to obtain the best compromise between cool running for separation resistance and cut, chip, tear and wear resistance, while incorporating synthetic into a portion of tread.

The final compound combination resulted in a synthetic content of 50% of the polymer used.

Tread Cap or Veneer: An all-synthetic compound with a polymer blend of 50% Diene and 50% oil-extended FRS. The synthetic portion of the tread is confined to essentially only the lugs of the design to keep its higher heat build-up characteristics (relative to natural rubber) away from the critical separation area of the tire on top of the tire carcass. The use of Diene imparts added wear and cracking resistance over the previous all oil-extended FRS tread compound (original contract work, Compound Line Up III), plus giving an improvement in low temperature flexibility.

Tread Base: An intermediate layer of a compound with a 75% natural rubber-25% Isoprene polymer blend, compounded to provide the best compromise between cool running and wear, cut, chip and tear resistance. The use of a predominantly natural rubber compound between the tread cap and carcass permits the use of the all-synthetic tread cap with no loss in separation resistance.

Tread Cushion: A separation-resistant layer compound lying between the tread base and tire carcass. This compound contains a polymer blend of 75% natural rubber and 25% Isoprene and is compounded for the best cool running features with the minimum sacrifice in wear, cut, chip and tear resistance. This compound in combination with the tread cap and tread base constitute the three-piece tread construction for the best overall compromise of tire compound properties.

Outer Body: Same as Tread Cushion.

Inner Body: Compounded for cool running and heat resistance, the Inner Body features a polymer blend of 75% natural rubber and 25% Isoprene.

Innerliner: Compounded with a polymer blend of 58% chlorobutyl, 24% natural rubber, and 18% Diene, this Innerliner features improved low temperature flexibility (due addition of Diene), over previous compound used in original contract tires, in addition to properties mentioned previously.

Remainder of Compounds:

Sidewall - Firestone standard Military Truck tire compound.

Others - Firestone standard Off-The-Road compounds.

Coatings - Firestone Coating A referred to under original contract compounding.

2. COMPOUND PROPERTIES

	<u>TREAD CAP</u>	<u>TREAD BASE</u>	<u>TREAD CUSHION</u>	<u>INNER BODY</u>	<u>INNERLINER</u>
<u>Normal (70°F) Stress-Strain</u>					
Tensile, psi	2850	3600	3675	3675	1275
300% Modulus, psi	650	1000	725	675	600
Elongation, %	710	590	645	610	560
<u>Tensile @ 275°F</u>					
Tensile, psi	650	825	725	525	-
Elongation, %	290	425	450	495	-
<u>Normal (70°F) Tensile After *Days @ 212°F</u>					
Tensile, psi	2475	1725	1275	1525	1175
Elongation, %	420	370	335	410	480
<u>Firestone Flexometer</u>					
Running Temp., °F	288	192	184	138	236
Deflection, %	18.7	12.7	26.0	24.7	24.7
Shore "A" Hardness	64	58	52	51	53
<u>Ring Tear</u>					
Normal-70°F, lb/in	525	300	350	575	-
-212°F. lb/in	300	150	150	225	-
<u>Brittle Point</u>					
ASTM D746-57T, °F.	-78	-54	-56	-59	-60

*Aging 6 days at 212°F. for Innerliner
2 days at 212°F. for All Others

3. TEST RESULTS

GENERAL CONSIDERATIONS

In view of the satisfactory performance of the previously mentioned three-piece tread construction for durability and the synthetic tread cap for wear in the Durability Tests, it was decided to use this compounding construction on the 29.5-25 16 Ply Rating SGG GOER tire manufactured for European Troop Tests. However, due to the synthetic's inherent weakness for crack growth, which evidenced itself quite prominently during the Durability Tests, modification of the synthetic tread cap stock was necessary.

TREAD COMPOUND MODIFICATIONS

The synthetic tread cap compound was modified in line with other Firestone compounding practices and experience to improve the compound's crack initiation and growth resistance. These modifications reduced the compound's ability to meet the Standard Military Ozone requirements; however, it is felt that the compound's resistance to atmospheric deterioration, especially with the protective coating used, is adequate. In general the compound's properties are similar to those of the tread cap compound listed under Durability Tests. The improvement in crack initiation and crack growth can be seen from the following data:

Firestone Groove Flexing Machine

	<u>Previous Compound</u>	<u>Modified Compound</u>	<u>Per Cent Improvement</u>
Crack Initiation (Minutes to Crk)	250	510	104
Crack Growth (Inches/ Hour)	.258	.110	.174

29.5-25 GOER TIRE DRUM TEMPERATURE
COMPARISON

Equipment: 70.5" diameter steel drum powered by Allis Chalmers 100 H.P.
AC Electric motor - 440 volts 495 RPM.

Brown Temperature Recorder and Copper-Constantan Thermocouples.

Test Features:

<u>Serial</u>	<u>Features</u>	
	<u>Design</u>	<u>Compounding</u>
K12500	Super Ground Grip Goer	11% Synthetic
K12600	Super Ground Grip Goer	52% Synthetic
K12700	Super Ground Grip Goer (With Grooves)	13% Synthetic
K12800	ND-CC Goer	14% Synthetic
K12900	ND-CC Goer	56% Synthetic

Test Conditions:

Load - 18,500 flat plate load

Speed - 17.1 MPH

Inflation - 40 psi

Ambient Temperature - 68°F

Test Results:

<u>Serial</u>	<u>Tread Temperature</u>			<u>Air Temp.</u>	<u>Miles Run</u>	<u>Final Inflation</u>
	<u>Center</u>	<u>Mid Point</u>	<u>Shoulder(Hot Spot)</u>			
K12500-2	179	197	208	144	150	48
K12600-1	201	221	229	149	150	50
K12700-4	177	191	196	145	150	49
K12800-2	196	206	222	147	150	50
K12900-2	227	230	240	142	113	47

Conclusions:

1. Using the Super Ground Grip Goer as a control (K12500) for a running temperature comparison of these three designs, we see that the Super Ground Grip Goer (with grooves) is 12° cooler running and the ND-CC Goer is 14° hotter running than this control.
2. There are two comparisons of the effect of synthetic content on running temperature:
 - A. K12500 (11%) vs. K12600 (52%)
(208°) (229°) +21°

B. K12800 (14%) vs. K12900 (56%)
(222°) (240°) +18°

This shows that the higher synthetic content is 18-21° hotter than the same tire with the lower synthetic content.

NOTE: These drum temperatures can not be construed as indicative of actual operating temperatures under these same conditions. Only a comparison of one vs. another can be made.

**29.5-25 GOER TIRE
ON-VEHICLE TEMPERATURE COMPARISON
CONTINUOUS HIGHWAY SERVICE**

Discussion

These on-vehicle temperature tests provide a comparison of the three designs (Super Ground Grip Goer, Super Ground Grip Goer with grooves, and ND-CC Goer) and also a comparison of high synthetic content (52 - 56%) vs. low synthetic content (11 - 14%).

All tires were tested on the same XM438 Goer Tanker with a gross vehicle weight of 69,800 lbs.

All tests were conducted on a 3-1/8 mile loop of highway which was part of the A.A.S.H.O. road test at Ottawa, Illinois. The duration of each test run was determined by the equilibrium point. When the temperatures leveled off, the tests were terminated. The tests were conducted 11-15, September 1961.

Test Features:

<u>Serial</u>	<u>Design</u>	<u>Features</u>	<u>Compounding</u>
K12500	Super Ground Grip Goer		11% Synthetic
K12600	Super Ground Grip Goer		52% Synthetic
K12700	Super Ground Grip Goer (With Grooves)		13% Synthetic
K12800	ND-CC Goer		14% Synthetic
K12900	ND-CC Goer		56% Synthetic

Test Conditions:

Load 69,800 lbs. G.V.W.

Inflation 40 psi drive, 30 psi trail

Speed 29 MPH Average.

Test Results (All Temperatures Corrected to 68° Ambient)

Inflation Actual Maximum

Type	Serial	Position	Cold	Hot	Ambient	Temp. (Corr.)	Hours Run
Super Ground Grip Goer	K12500-1	RF	40	52	65°	241°	4.7
Super Ground Grip Goer	K12600-1	LF	40	51	65°	272°	4.7
Super Ground Grip Goer	K12500-2	LR	30	40	65°	234°	4.7
Super Ground Grip Goer	K12600-2	RR	30	40	65°	239°	4.7
Super Ground Grip Goer (With Grooves)	K12700-2	RF	40	51	62°	217°	5.7
Super Ground Grip Goer (With Grooves)	K12700-1	LF	40	50	62°	219°	5.7
Super Ground Grip Goer (With Grooves)	K12700-3	LR	30	41	62°	213°	5.7
Super Ground Grip Goer (With Grooves)	K12700-4	RR	30	41	62°	206°	5.7
ND-CC Goer	K12800-1	RF	40	54	63°	233°	4.5
ND-CC Goer	K12900-1	LF	40	54	63°	255°	4.5
ND-CC Goer	K12800-2	LR	30	43	63°	208°	4.5
ND-CC Goer	K12900-2	RR	30	43	63°	236°	4.5

Conclusions

1. The effect of design on running temperature can be readily determined since one tire of each design was run under the same conditions using the Super Ground Grip Goer (K12500) as a control:

Type	Serial	Position	Maximum Temperature
SGG Goer	K12500-1	RF	241° Par
SGG Goer (With Grooves)	K12700-2	RF	217° -24°
ND-CC Goer	K12800-1	RF	233° + 8°
SGG Goer	K12500-2	LR	234° Par
SGG Goer (With Grooves)	K12700-3	LR	213° -21°
ND-CC Goer	K12800-2	LR	208° -26°

These differences might be attributed to variations in the individual tires such as base gauge, etc.

2. The effect of synthetic content on tire operating temperature can also be determined. Four direct comparisons are available.

<u>Serial</u>	<u>% Synthetic</u>	<u>Position</u>	<u>Maximum Temperature</u>	
K12500-1	11%	RF	241°	+31°
K12600-1	52%	LF	272°	
K12500-2	11%	LR	234°	+ 5°
K12600-2	52%	RR	239°	
K12800-1	14%	RF	233°	+22°
K12900-1	56%	LF	255°	
K12800-2	14%	LR	208°	+28°
K12900-2	56%	RR	236°	

Ave. Difference +22°

3. These tests determined that at inflation of 40 psi, drive and 30 psi, trail, the Super Ground Grip Goer tires (with grooves - K12700) should operate safely in continuous service at speeds under 30 MPH and at an ambient temperature of 68°.

We use 250°F as a critical temperature, and as an ambient temperature correction factor, we use 1/2°F tire temperature change for each 1°F. ambient change. It can be seen from these temperatures that at higher ambient temperatures all of the other designs would be marginal. Since it is desirable to use as high a synthetic content as possible, the Super Ground Grip Goer tire (with grooves) is the only one capable of continuous highway operation at high ambient temperatures when produced with the high synthetic construction.

TRACTION TEST SUMMARY

SAND, COMPRESSIBLE SOIL, AND NON-COMPRESSIBLE SURFACE

Discussion: The data and resulting conclusions shown in this summary have been abstracted from:

Final Report
Phase I
Project 20-1-102

Traction Ability of Various 29.5-25 Goer Tires in Sand, in a Compressible Soil, and on a Non-Compressible Surface.

This report was prepared by Nevada Automotive Test Center, Carson City, Nevada for Le-Tourneau Westinghouse Company in September, 1962.

OBJECT

The object of this test program was to evaluate the tractive ability of the following test tire groups (each featuring a difference in tread design) in sand, in compressible soil and on non-compressible surface.

Group A: Firestone Ground Grip (Control Tires),
16 PR Directional Design, 29.5-25.
Serial numbers K-4300-9 and K-4300-14.

Group B: Firestone ND-CC Goer, 16 PR
29.5-25.
Serial numbers K-12900-2 and K-12900-1.

Group C: Firestone Super Ground Grip Goer, 16 PR,
Grooved Lug, 29.5-25.
Serial numbers K-21700-4 and K-12700-3.

Group D: Firestone Super Ground Grip Goer, 16 PR,
Solid Lug, 29.5-25.
Serial numbers K12500-1 and K-12600-1.

CONCLUSIONS

SAND

In prepared sand simulating the loose "blow" sand common to the lee side of beach and desert dunes the initial desirable inflation pressure increments of 40, 30 and 20 PSI were predictably high for vehicle operation in the type of sand available at the test site. 20 PSI was found to be the maximum test pressure to which the tires could be inflated to permit movement of the test vehicle from highway to the sand course over a sand road traversable by jeep and pickup.

With maximum sand tire inflation pressure established at 20 PSI, 16 and 12 PSI were arbitrarily selected as the lower increments at which data would be generated.

Little significant difference in performance existed between these tires at 20, 16 and 12 PSI.

The 12 PSI inflation pressure would not be practical for any of these tires due to the severe traction buckle which appeared at this low pressure. Two of the eight tires tested experienced slippage between tire and rim.

The sand gradeability of the 64,000 lb. Goer vehicle equipped with Conventionally designed tires on all four drive wheels is calculated to be as follows:

Tire Group	A			B			C			D		
Inflation, Press.	20	16	12	20	16	12	20	16	12	20	16	12
Gradeability, %	25	30	34	24	29	34	(1)	29	32	27	29	32
Gradeability Rating as compared with Control	100	100	100	96	97	100	(1)	97	94	108	97	94
Travel Efficiency Rating as compared with Control	100	100	100	95	103	96	(1)	103	101	100	104	103

(1) Could not negotiate sand course with drawbar load.

COMPRESSIBLE SOIL WITH GROUND COVER

As opposed to sand, tires in compressible soil continue to develop progressively more drawbar as travel efficiency diminishes (increased wheel spin). This being the case, comparative performance in terms of drawbar must be judged at comparable travel efficiency points. For specific comparisons see SUMMARY OF TEST RESULTS, Tractive Ability, Compressible Soil with Ground Cover. Of the experimental tires, the ND-CC Goer design, Group B, provided maximum drawbar pull under these conditions.

CONCLUSIONS (CONTINUED)

NON-COMPRESSIBLE SURFACE

Under these conditions, the Super Ground Grip Goer, Group D, provided the maximum drawbar pull of any of the experimental designs.

SUMMARY OF TEST RESULTS

SUMMARY OF TEST RESULTS (Continued)

Tractive Ability, Compressible Soil with Ground Cover

SUMMARY OF TEST RESULTS (Continued)

Tractive Ability, Compressible Soil with Ground Cover
Averaged Drawbar Values (at 90, 75 and 60%
Travel Efficiency) Rated Against Group A.

<u>Group</u>		<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
Infl. Press., 40 PSI	14800	16300	14100	14900	
Rating	100	110	95	101	
30 PSI	15400	16300	13400	14500	
Rating	100	106	87	94	
20 PSI	15300	14600	13800	13800	
Rating	100	95	90	90	

SUMMARY OF TEST RESULTS (Continued)

Intractive Ability, Non-Compressible Surface (Continued)

<u>% T.E.</u>	40 PSI			30 PSI			20 PSI		
	<u>90</u>	<u>75</u>	<u>60</u>	<u>90</u>	<u>75</u>	<u>60</u>	<u>90</u>	<u>75</u>	<u>60</u>
A									
Firestone Ground Grip WB (Control Tires) 16 PR	Drawbar Rating	18000 100	21300 100	21900 100	16500 100	21200 100	21700 100	7800 100	19000 100
	Est. Grade. (4 Wh. Dr.)	53	63	64	49	62	64	23	56
	Calc. Grade (2 Wh. Dr.)	28	33	34	26	33	34	12	30
B									
Firestone NDCC Goer 16 PR	Drawbar Rating	12700 71	22100 104	24300 110	7700 47	17400 82	23200 107	8400 107	18700 98
	Est. Grade. (4 Wh. Dr.)	37	65	71	23	51	68	25	55
	Calc. Grade. (2 Wh. Dr.)	20	35	38	12	27	36	13	29
C									
Firestone Super Ground Grip Goer 16 PR, Grooved Lug	Drawbar Rating	9300 52	19100 90	24300 110	7500 45	15900 75	22900 106	7500 96	16300 86
	Est. Grade. (4 Wh. Dr.)	27	56	71	22	47	67	22	48
	Calc. Grade. (2 Wh. Dr.)	15	30	38	12	25	36	12	25
D									
Firestone Super Ground Grip Goer, 16 PR, Solid Lug	Drawbar Rating	14400 80	20600 97	21500 98	14300 87	20900 99	22100 102	14300 183	20600 108
	Est. Grade. (4 Wh. Dr.)	42	61	63	42	61	65	42	61
	Calc. Grade. (2 Wh. Dr.)	23	32	34	23	33	35	23	32

SUMMARY OF TEST RESULTS (Continued)

Tractive Ability, Non-Compressible Surface

Averaged Drawbar Values (at 90, 75 and 60% Travel Efficiency)
Rated Against Group A.

<u>Group</u>		<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
Infl. Press., 40 PSI	20400	19700	17600	18800	
Rating	100	97	86	92	
30 PSI	19800	16100	15400	19100	
Rating	100	81	78	96	
20 PSI	15700	16500	15200	18900	
Rating	100	105	97	120	

FINAL REPORT

DURABILITY TEST OF GOER TIRES
Phase III

Project 20-1-110

July 1963

Prepared For
LeTourneau-Westinghouse Company
Under Test Directive 224 Revised

Prepared By: Walter H. Statton
Walter H. Statton
Vice President

Approved By: Henry C. Hodges
Henry C. Hodges
President

Nevada Automotive Test Center
Carson City, Nevada

A Division of Hodges Transportation Inc.

FINAL REPORT

Project 20-1-110

Upper Photograph

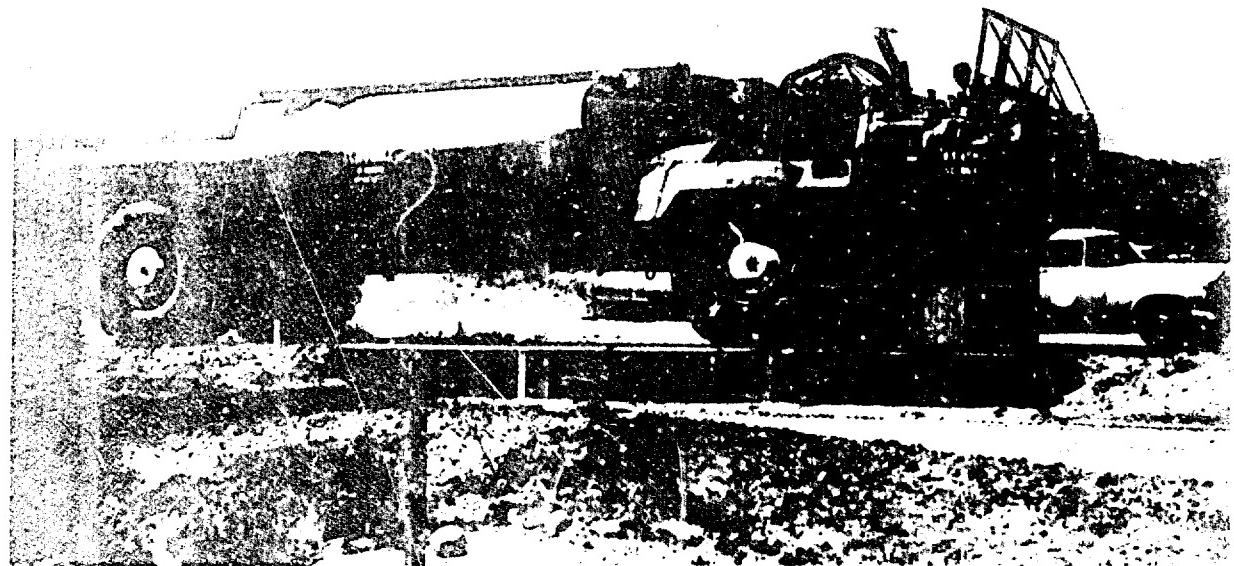
XH 43822 Fuel Tank Truck being weighed prior
to "Ride" evaluation

Lower Photograph

Three (3) Commercial Model "C" Tournapull
Vehicles used in Tread Wear and Durability Test

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FINAL REPORT

Project 20-1-110

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APPENDICES A AND B	Under Separate Cover

HISTORY

In August 1962 the Nevada Automotive Test Center, A Division of Hodges Transportation Inc., conducted an Engineering Study (Project 20-1-102) of the influence of tire tread design and carcass construction on the tractive efficiency of 29.5 - 25 tires applicable to unsprung four wheel vehicles such as the Model "C" Tournapull and the ATAC "Goer".

In February 1963 two experimental tire groups and one control (Standard "Goer" 29.5 - 25) tire group were applied to three commercial Model "C" Tournapull "test bed" vehicles for the purpose of establishing the comparative durability and tread wear performance of these tires when subjected to semi-continuous operation over paved highways, "washboard" secondary roads and cross-country trails.

OBJECT

The three tire test groups selected for this durability and tread wear study featured significant differences and the test program was set up to segregate the effect of these differences in terms of tire durability and tread wear:

Tire Group A, the standard 29.5 - 25 directional tread "Goer" tires, featured 16 ply conventional construction and natural rubber tread.

Tire Group B, the experimental 29.5 - 25 non-directional tread tires, featured radial ply construction.

Tire Group C, the experimental 29.5 - 25 directional tread tires, featured 16 ply conventional construction and synthetic rubber tread.

Two additional tire groups were available for durability and tread wear testing (Groups D and E) should premature failures develop in the original test tire groups.

Tire Group D, the experimental 29.5 - 25 non-directional tread tires, featured 16 ply conventional construction.

Tire Group E, the experimental 29.5 - 25 directional tread tires, featured radial ply construction.

One additional group of non-directional radial ply construction tires (Group F) with the same features as Group B was available for engineering investigation.

TEST PLAN

The tread wear and durability test plan established a requirement for the following:

A maximum of 20,000 vehicle miles per tire test group divided into 8,000 miles of pavement operation, 8,000 miles of secondary road operation and 4,000 miles of cross-country trail operation.

Front tire loads of approximately 19,400 lbs. per tire and rear tire loads of 16,000 lbs. per tire simulating the tire loads of the ATAC "Goer" fuel tank truck, XM 438E2.

Measurements of tread wear and tire deterioration each 2,500 miles of operation.

Rotation of test tires from vehicle to vehicle each measurement period to equate vehicle "test bed" differences.

Test speeds averaging 25 MPH on pavement, 25 MPH on secondary roads and 8 MPH over cross-country trails to be maintained commensurate with driver and vehicle safety.

Tire inflation at the maximum level permitted by cross-country terrain conditions in terms of driver and vehicle fatigue limits at the minimum average speed requirement of 8 MPH.

Tire temperatures on the pavement course.

Driver observations of vehicle "ride" and performance as influenced by tire reaction.

The specific test plan and procedures are set forth in detail in TEST PROGRAM of this report.

CONCLUSIONS

The following conclusions may be drawn from the data generated under the specific conditions of this test program as summarized in TEST RESULTS.

Tire Tread Wear

Regardless of tread design, tires of radial ply construction (Groups B and E) provide a significantly lower tread wear rate than tires of conventional construction (Groups A, C and D). Group B was 14% worn compared with A-79%, C-35% and D-32% worn at equal mileage.

With like tire construction, non-directional tread tires (Groups B and D) provide a lower tread wear rate than directional tread tires (Groups A, C and E).

The synthetic directional tread conventional construction tires (Group C) provide a significantly lower tread wear rate than the natural rubber directional tread conventional construction tires (Group A).

On the Model "C" Tournapull "test beds" rear tire wear rate exceeded front tire wear rate; however, in terms of irregular wear the non-directional design is not sensitive to axle position, whereas the directional design is sensitive.

Directional tread conventional construction tires (Group A) exhibit almost 100% higher lug pressure on the ground than do the non-directional tread radial ply tires (Group B) which increases unit rate of wear.

Tire Durability

The synthetic directional tread conventional construction tires (Group C) developed substantially greater tread cracking than the natural rubber tread tires (Group A) of the same construction.

Conventional construction tires (Groups A and C) are significantly more durable than the radial ply construction tires (Group B) experiencing no carcass failures of the original eight test samples, whereas the radial ply construction experienced three carcass failures and one tread separation of the original four test samples and one carcass failure of the three replacement tires subjected to test.

The relative durability of the two additional tire groups cannot be assessed as the accumulated test miles authorized for a tread wear comparison of these groups (Groups D and E) were respectively 7,500 and 2,500 miles which were not adequate for durability comparison.

CONCLUSIONS (Contd.)

Tire Temperatures

The non-directional radial ply tires (Group B) under normal conditions of pavement test operation ran at a slightly lower mean temperature (198°F) than the Groups A and C directional conventional tires (202°F).

The non-directional conventional tires (Group D) under normal conditions of pavement test operation ran significantly cooler (210°F) than the Group E directional radial ply tires (237°F); however, while the operating conditions were equivalent during the time these temperatures were recorded the accumulated group tire mileages were not (Group D-7,500 miles, Group E-2,500 miles).

In the pavement operation established for this test (8 hours continuous) tire Groups A, B, C and D will not generate temperatures in excess of 235°F providing all tires are normal, i.e., no separations or traumatic frictional generators.

Rolling Resistance

The directional conventional tires (Groups A and C) and the non-directional radial ply tires (Group B) were analyzed in terms of their relative influence on vehicle fuel consumption. A comparison of the fuel consumed by the three test vehicles applied to each tire group for an equal number of miles represents a rate of fuel consumption chargeable to each tire group without regard for vehicle differences. The foregoing disregards many possible variables but a trend was established from these data which showed a 6% improvement in the rate of fuel consumption attributable to the non-directional radial ply tires (Group B) when compared with the directional conventional tires (Group A) and an 8% improvement when compared with the directional conventional tires (Group C).

CONCLUSIONS (Contd.)

Instrumented "Ride" Study

Compared with the Model "C" Tournapull, the "Goer" Tanker at rated load provides significantly better "ride" characteristics on rough pavement and secondary road surfaces regardless of the influence of the tires.

In cross-country over natural obstacles the vehicle reaction is sharply sensitive to tire reaction which permits the equating of vehicle differences by tire selection, i.e., the "Goer" equipped with radial ply tires (Group F) is equally as acceptable as the Model "C" Tournapull equipped with conventional directional tires (Group A), whereas when these tires are reversed in vehicle assignment the two vehicles are equally "ride" deficient.

On pavement and secondary road surfaces the "ride" of the "Goer" Tanker equipped with non-directional radial ply tires (Group F) is essentially insensitive to limited tire pressure change, whereas the Model "C" Tournapull "ride" is extremely sensitive. Equipped with conventional directional tires (Group A) both vehicles exhibit a slight pressure change sensitivity.

By comparison the "ride" characteristics of the non-directional conventional tires (Group D) are considered deficient in any "rough" area on any surface when mounted on the Model "C" Tournapull. The non-directional radial ply tires (Group E) provide the best over-all Model "C" Tournapull "ride" on pavement and secondary road surfaces and better cross-country "ride" than the non-directional radial ply (Group F). Assuming the influence of the "Goer" on the cross-country "ride" of the Group F tires would hold true for the directional radial ply Group E tires, the Group E tires would provide a significantly better over-all "Goer" "ride" than any other tire group tested.

Using the Model "C" Tournapull as a "test bed" and under the eleven different test conditions in the "Ride" Study to which all tire groups were subjected the directional conventional (Group A) tires exceeded the human fatigue limit(1) under five conditions and the vehicle fatigue limit(2) under two conditions; the non-directional radial ply tires (Group F) exceeded the human fatigue limit under six conditions and the vehicle fatigue limit under three conditions; on the same comparative basis, the non-directional conventional ply tires (Group D) exceeded the human fatigue limit seven times and vehicle fatigue limit four times; and the directional radial ply tires (Group E) exceeded the human fatigue limit four times and the vehicle fatigue limit three times.

- (1) Acceptable "Human" Continuous Fatigue Limit of .89 (Ride Index), as Interpreted from Goldman's "Unpleasant" Limit.
- (2) Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index), as Interpreted from Goldman's "Intolerable" Limit.

CONCLUSIONS (Contd.)

Instrumented "Ride" Study (Contd.)

Using the "Goer" Tanker as a "test bed" and under the same conditions applied to the Model "C" Tournapull "test bed" the directional conventional (Group A) tires exceeded the human fatigue limit three times and the vehicle fatigue limit once, whereas the non-directional radial ply (Group F) tires exceeded the human and vehicle fatigue limit only once under the single cross-country condition.

Instrumented Shallow Mud Traction Study

Only the directional conventional (Group A) tires and the non-directional radial ply (Group F) tires were subjected to this Mud Traction Study and the following conclusions may be drawn from their performance.

The directional conventional (Group A) tires depend upon increased ground pressure for increased traction, whereas the non-directional radial ply (Group F) tires depend upon decreased ground pressure for increased traction.

At their optimum inflation pressure within the range investigated (15-55 psig) the maximum traction of the two groups being compared were equal at 55 psig for the Group A tires and 15 psig for the Group F tires.

The pressure print profile of the two groups at their maximum traction indicated a single high pressure contact in the crown of the Group A tires and two high pressure contacts at the shoulders of the Group F tires.

At their maximum traction the static lug ground pressure of the Group A tires is 228 PSI and the Group F tires is 48 PSI which influences tire flotation characteristics.

The vehicle ground clearance is reduced by the inflation pressure reduction required by the Group F tires.

In shallow mud the tread void areas of the Group A tires are cleared of mud buildup at 15 psig inflation, whereas the Group A are substantially loaded. At 55 psig inflation the Group A tread void areas are cleared of mud buildup and the Group F tires are substantially loaded.

CONCLUSIONS (Contd.)

Instrumented Shallow Mud Traction Study (Contd.)

CONSIDERATIONS FOR IMPROVING "GOER" MUD TRACTION

To achieve acceptable mobility, the "Goer" vehicle equipped with non-directional radial ply tires should not be operated in shallow mud with more than 25 psig front tire inflation pressure and 20 psig rear tire inflation pressure, whereas the directional conventional (Group A) tires should not be operated with less than 45 psig front tire inflation pressure and 40 psig rear tire inflation pressure.

To achieve acceptable soil trafficability (mud track pass factor) neither Group A nor Group F should be inflated to more than 25 psig.

These data indicate that in deep mud the directional tread (Group A) tires at 35, 45 or 55 psig inflation can negotiate a more severe condition in forward travel than in reverse; consequently, consideration should be given to what inflation pressure might be used to extricate the vehicle when forward travel is no longer possible.

Serious consideration should be given to evaluating the deep mud potential of:

1. Non-directional conventional and radial ply tires.
2. Directional conventional and radial ply tires.

TEST RESULTS

Table I summarizes the results of the Tire Durability Test in terms of test miles to removal and tread wear rate.

Table I

	Tire Groups				
	A	B	C	D	E
Average Test Miles Per Tire Sample ⁽¹⁾	10,022	8,604	15,040	7,509	2,541
Reason for Removal	Worn Smooth	Radial Cracks	Worn Smooth	Test Terminated	Test Terminated
Durability Rating, %	100	86	150	--	--
Tread Wear, Average Miles/Mil ⁽²⁾	6.1	29.9	12.2	16.3	20.3
Tread Wear Rating, %	100	490	200	267	333

(1) The sum of the failed tire mileages divided by the number of failed tires equals average test miles per tire sample.

(2) These averages are based on two measurement locations (shoulder) and do not include crown wear. (See Summary of Tire Tread Wear; Final, By Period.)

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TEST RESULTS (Contd.)

Table II summarizes the result of the "Ride" Study comparing tire group performance in terms of vehicle "ride" index values (See Appendix A, "Ride" Study). A "ride" index value of 0.89 is defined as being the acceptable limit of human fatigue for continuous operation.

TABLE II

<u>Condition</u>	<u>Tire Groups</u>						
	<u>A</u>	<u>F</u>	<u>D</u>	<u>E</u>			
Front Tire psig	40	50	40	50	40	50	40
Rear Tire psig	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>
<u>"Ride" Index</u>							
Pavement							
#1, Smooth	0.35	0.68	0.51	0.50	0.60	0.30	0.50
#2, Rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.80	<u>4.60*</u>	<u>2.00*</u>	<u>2.15*</u>
Secondary							
#1, Smooth	0.54	0.65	0.50	<u>1.20</u>	0.44	<u>0.38</u>	0.22
#2, Smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.24	<u>1.90</u>	0.28
#3, Rough	0.85	<u>2.38*</u>	<u>0.92</u>	<u>2.90*</u>	<u>0.91</u>	<u>4.30*</u>	0.75
Cross-Country							
Rough	<u>2.7*</u>	--	<u>6.2*</u>	--	<u>10.2*</u>	--	<u>5.4*</u>

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

Table III summarizes the result of the "Ride" Study comparing the performance of the Model "C" Tournapull with the "Goer" Tanker, in terms of vehicle "Ride" index value (see Appendix A, Ride Study). A "ride" index of 1.31 is defined as being the acceptable limit of vehicle fatigue for continuous operation (approximately 0.6 to 0.9 G). (See CHART LEGEND, Figures 1 and 2.)

TABLE III

Vehicle Tire Group Condition	Vehicle "Ride" Indices							
	Model "C" Tournapull				"Goer" Tanker			
A	F	A	F	A	F	A	F	
Inflation, Front, psig	40	50	40	50	40	50	40	50
Inflation, Rear, psig	30	40	30	40	30	40	30	40
Pavement					<u>"Ride" Index</u>			
#1, Smooth	0.35	0.68	0.51	0.50	0.22	0.27	0.31	0.29
#2, Rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.80	0.57	0.65	0.80	0.75
Secondary								
#1, Smooth	0.54	0.65	0.50	<u>1.20</u>	0.22	0.56	0.20	0.18
#2, Smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.20	<u>1.40</u>	0.35	0.38
#3, Rough	0.85	<u>2.38*</u>	<u>0.32</u>	<u>2.90*</u>	0.51	<u>0.90</u>	<u>0.58</u>	0.62
Cross-Country								
Rough	<u>2.70*</u>	--	<u>6.20*</u>	--	<u>5.70*</u>	--	<u>2.90*</u>	--

	Comparison of Mean Vehicle "Ride" Indices					
	Pavement		Secondary		Cross-Country	
	Smooth	Rough	Smooth	Smooth	Rough	Pough
Goer # 40-30 psig	0.27	0.63	0.21	0.26	0.53	<u>4.30*</u>
"C" Pull # 40-30 psig	0.40	<u>1.70</u>	0.52	0.45	0.89	<u>4.45*</u>
Goer # 50-40 psig	0.28	0.78	0.37	0.89	0.76	--
"C" Pull # 50-40 psig	0.59	<u>3.35</u>	<u>0.93</u>	<u>1.31</u>	<u>2.64*</u>	--

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

Table IV summarizes the results of the shallow Mud Traction Study (See Appendix 3, Mud Traction Study) of the directional tread conventional construction 29.5 - 25 tires and the non-directional tread radial ply 29.5 - 25 tires in terms of the influence of inflation pressure on tractive efficiency.

TABLE IV

Inflation Pressure	Maximum Drawbar, lbs.		% Travel Efficiency J		Static Ground-Lug Pressure PSI(2)	
	Group A	Group F	Maximum Drawbar	Group A	Group F	Group A
55	9800	6100	17	26	228	113
45	8200	6800	30	31	146	85
35	7800	7150	30	27	109	62
25	7600	8750	40	32	87	56
15	(7550)(1)	9800	--	36	72	48

(1) Extrapolated from inflation pressure-maximum drawbar curve of Groups A and F.

(2) At 55 PSI the A Group penetrated to a depth of 2.25" in the crown area of the track and the F Group penetrated to a depth of 1.75" in the same area. At 25 PSI the A Group penetrated 0.25" evenly across track and the F Group penetrated to depth of 2.00" in the shoulder area of the track.

TEST RESULTS (Contd.)

Table V summarizes the calculated influence of the directional conventional tire (Group A) and the influence of the non-directional radial ply tire (Group F) on the shallow mud traction of the "Goer" Tanker.

TABLE V

Maximum Drawbar and Gradeability

Inflation Pressure	4 Wheels Driving				2 Wheels Driving			
	Group A		Group F		Group A		Group F	
	D.B.	Grade	D.B.	Grade	D.B.	Grade	D.B.	Grade
55	17950#	25%	11500#	16%	9600#	13%	6100#	8%
45	15100	21	12200	17	8100	11	6500	9
35	14350	20	13000	18	7700	11	6900	10
25	13650	19	15800	22	7300	10	8400	12
15	13650	19	17950	25	7250	10	9600	13

Maximum Drawbar and Gradeability at 75% Travel Efficiency

Inflation Pressure	4 Wheels Driving				2 Wheels Driving			
	Group A		Group F		Group A		Group F	
	D.B.	Grade	D.B.	Grade	D.B.	Grade	D.B.	Grade
55	8200#	12%	2800#	4%	4300#	6%	1500#	2%
45	8600	12	6500	9	4600	6	3450	5
35	9200	13	7900	11	5000	7	4200	6
25	10800	15	8600	12	5750	8	4600	6
15	--	--	11500	16	--	--	6100	8

D.B. = Drawbar

Grade = Gradeability

TEST RESULTS (Contd.)

Table VI summarizes the calculated performance of the "Goer" Tanker in terms of maximum traction (maximum performance) and at 75% travel efficiency.

TABLE VI

<u>Pressure</u>	4 Wheel Drive Comparative Performance Ratings			
	Maximum Performance		@ 75% Travel Efficiency	
	<u>Group A</u>	<u>Group F</u>	<u>Group A</u>	<u>Group F</u>
55	100%	64%	100%	33%
45	100	80	100	75
35	100	90	100	85
25	100	115	100	80
15	100	131	--	--

TEST RESULTS (Contd.)

Table VII summarizes the tire temperatures on pavement without regard for ambient or pavement temperatures as tire temperatures were recorded under equivalent conditions in each period.

TABLE VII

2,500 Mile Test Period		Tread Temperature of Test Tires on Pavement						Group E Max. of Avg. of
		Group A Max. of Avg. of F	Group B Max. of Avg. of F	Group C Max. of Avg. of F	Group D Max. of Avg. of F	Group E Max. of Avg. of F		
Low temperatures recorded due to probe position.								
1st								
2nd, 3rd	230	199	275*	182	224	195	--	--
4th	220	198	245*	203	205	199	--	--
5th	265*	209	240*	209	234	213	--	--
Mean Temperature								
6th		--	--	200	189	216	203	256
7th		--	--	--	--	233	216	265
Mean Temperature						--	--	242
							210	237

* Areas influenced by tread condition.

TEST RESULTS (Contd.)

Table VIII summarizes a comparison of vehicle fuel consumption as an index of tire rolling resistance.

TABLE VIII

	Pavement	Average Miles per Gallon Secondary & Cross-Country	Over-All
Group A	2.77	1.91	2.18
Group B	2.81	2.05	2.30
Group C	2.68	1.89	2.14

Over-All Rating % Based on Average Miles/Gallon

<u>Group A</u>	<u>Group B</u>	<u>Group C</u>
100%	106%	98%

RECOMMENDATIONS

The scope of Project 20-1-110 has generated specific conclusions with respect to the tires and vehicles evaluated during this program. Deserving additional investigation to satisfy the specific questions arising from the results of this program are the following:

Tread Wear and Durability

The directional radial ply construction (Group E) and the non-directional conventional construction (Group D) tires should be subjected to additional durability test mileage before a valid performance comparison can be drawn for all tires considered in Project 20-1-110.

"Ride" Evaluation

The "Goer" Tanker vehicle exhibits a marked improvement in "Ride" over the commercial Model "C" Tournapull "test beds" on pavement and secondary roads, but not over cross-country trails with the inflation pressures recommended for the "Goer". As the "Goer" is equipped with a central self inflation system, all tires considered for "Goer" application should be judged in terms of cross-country "Goer" ride index vs inflation pressure curve in order to determine each tire group's tactical speed limit when negotiating cross-country.

• "Goer" Mud Traction

In shallow mud the non-directional radial ply tires (Group F) were found to be as effective as the directional conventional construction (Group A) tires when the non-directional tires were inflated at 15 psig and the directional tires were inflated at 55 psig. The effect of this marked difference in inflation pressure and consequent reduction in ground contact pressure for the Group F tires should be measured in deep mud where underbody clearance not tire traction may be the factor limiting mobility. The directional radial tires (Group E) and the non-directional conventional construction tires should be evaluated in both shallow and deep mud to determine the separate effects of radial ply versus conventional construction and non-directional versus directional tread on mud traction. The influence of vehicle configuration should be assessed under these same conditions by measuring the percent effectiveness of the "Goer" rear wheel drive in mud.

DISPOSITION OF TIRES SUBJECTED TO TEST

Group A, Firestone Super Ground Grip Goer H.D. Directional (Control)

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
A-1	K 25300-14	10,022	Outside shoulder worn smooth.	None
A-2	K 25300-18	10,022	Both shoulders worn smooth.	None
A-3	K 25300-15	10,022	Inside shoulder worn smooth.	None
A-4	K 25300-16	10,022	Test terminated at this mileage.	None

Group B, U.S. Royal Tactical M.S. Radial Ply Construction Non-Directional

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
B-1	EX 1808	7,231	Air loss above flipper.	B-6
B-2	XF 1867	10,876	Air loss at radial crack.	B-7
B-3	GR 1122	6,097	Tread separation inside shoulder.	B-5
B-4	GR 1351	13,306	Air loss at radial crack.	None
B-5	GR 1099	7,209	Test terminated.	None
B-6	GR 1177	5,512	Tread separation and air loss at radial crack.	Non-Test Spare
B-7	GR 1037	2,430	Test terminated	None

DISPOSITION OF TIRES SUBJECTED TO TEST (Contd.)

Group C, Firestone Super Ground Grip Goer Directional

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
C-1	K 25500-5	15,040	Near worn smooth condition outside shoulder.	None
C-2	K 25500-4	15,040	Outside shoulder worn smooth.	None
C-3	K 25500-3	15,040	Test terminated.	None
C-4	K 25500-2	15,040	Test terminated.	None

Group D, Firestone NDMS

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
D-1	K 26400-5	7,509	Test terminated.	None
D-2	K 26400-4	7,509	Test terminated.	None
D-3	K 26400-1	7,509	Test terminated.	None
D-4	K 26400-3	7,509	Test terminated.	None

Group E, U.S. Royal Radial Ply Construction Directional

<u>Tire Code</u>	<u>Serial Number</u>	<u>Total Test Miles</u>	<u>Reason for Removal</u>	<u>Replacement Tire</u>
E-1	CD 1732	2,541	Test terminated.	None
E-2	CD 1706	2,541	Test terminated.	None
E-3	CD 1714	2,541	Test terminated.	None
E-4	CD 1658	2,541	Test terminated.	None

SUMMARY OF TIRE TREAD WEAR

1. Final

Tire Group	Physical Dimensions				
	A	B	C	D	E
Total Miles	10,022	13,305(1)	15,040	7,509	2,541
Cross Section Growth, %	1.1	0.7(2)	1.6	1.7	0.0
Outside Diameter Growth, %	0.1	(3)	0.6	(3)	0.2
Final Shore "A" Hardness	57	57(2)	64	62	63

Tire Group	Tread Wear at Shoulders				
	A(4)	B(5)	C(6)	D	E
Mils Loss, Group	9912	3296	8181	3686	1001
Miles/Mil, Group	6.1	29.9	12.2	16.3	20.3
Rating, Group (Based on Miles/Mil)	100	490	200	267	333
Mils Loss, Front	4256	1414	3385	1724	491
Miles/Mil, Front	7.1	35.4	14.8	17.4	20.7
Rating, Front (Based on Miles/Mil)	100	499	208	245	292
Mils Loss, Rear	5656	1882	4796	1962	510
Miles/Mil, Rear	5.3	25.7	10.4	15.3	19.9
Rating, Rear (Based on Miles/Mil)	100	485	196	289	375
% Worn, Group	79.2	31.0	65.3	32.3	8.4
% Worn, Front	34.0	13.3	27.0	15.1	4.1
% Worn, Rear	45.2	17.7	38.3	17.1	4.3

- (1) Tire B-4 accumulated 13,306 test miles before failure. All other original test tires and one replacement tire failed prior to this mileage.
- (2) Based on the seven samples tested.
- (3) Due to tire design no crown measurements could be taken to correct Outside Diameter on these groups.
- (4) One or both of the shoulder measurement areas had worn away on three of the four test tires at 10,022 test miles. Figures shown represent wear rates through 7,522 test miles (last measurement period before worn smooth condition).
- (5) Figures are based on the performance of the seven tire samples at the last valid measurement period of each tire.
- (6) Figures based on 12,525 mile measurement period due to one tire worn smooth at 15,040 mile measurement period.

SUMMARY OF TIRE TREAD WEAR (Contd.)

1. Final (Contd.)

As the only measurement positions common to all tire groups tested were the shoulders it was felt that a basis of comparison should be drawn from these data; however, even this must be weighed by the fact that there is a wide variation in mileage between the individual groups tested and the ratings even though based on miles per mil are on a total mileage; therefore, the figures do not reflect a true figure as it would if all tires had run equal miles.

A further comparison can be made on the three groups of tires whose design permitted a crown measurement. The following data indicates the tread wear across the tread face rather than in the fastest wearing area.

Tire Group	Tread Wear at Shoulders and Crown		
	A	C	E
Total Miles	7,522	12,525	2,541
Mils Loss, Group	11351	9861	1594
Miles/Mil, Group	8.0	15.2	19.1
Rating, Group (Based on Miles/Mil)	100	190	239
Mils Loss, Front	5179	4347	787
Miles/Mil, Front	8.7	17.3	19.4
Rating, Front (Based on Miles/Mil)	100	199	223
Mils Loss, Rear	6172	5514	807
Miles/Mil, Rear	7.3	13.4	18.9
Rating, Rear (Based on Miles/Mil)	100	184	259
% Worn, Group	61.3	53.2	8.9
% Worn, Front	28.0	23.5	4.4
% Worn, Rear	33.3	29.7	4.5

SUMMARY OF TIRE TREAD WEAR (Contd.)

2. by Period

Tread wear measurements are based on two shoulder measurement locations on the B Group (U.S.) tires and on two and three locations, two shoulder and one crown, on the A and C Groups (Firestone). The shoulder measurements are located 2 inches each side of crown, and are taken in a position around the circumference of the tire. The A, B and C Groups are compared on the basis of two measurement locations and the A and C Groups are additionally compared on the basis of three measurement locations.

Tire Group	Firestone				U.S. 3
	A	B	C	D	
Miles > Meas.	2,520		2,520		2,520
No. of Meas. Locations	2	3	2	3	2
Mils Loss (Group)	2239	2862	848	1465	584
Miles/Mil (Group)	9.0	10.6	23.8	20.6	34.5
% Worn (Group)	17.9	15.5	6.8	7.9	5.5
Mils Loss (Front)	1039	1416	356	719	331
Miles/Mil (Front)	9.7	10.7	28.3	21.0	30.5
% Worn (Front)	16.5	15.2	5.7	7.8	6.3
Mils Loss (Rear)	1200	1446	492	746	253
Miles/Mil (Rear)	8.4	10.5	20.5	20.3	39.8
% Worn (Rear)	19.1	15.7	7.9	8.1	4.7
Miles > Meas.	5,022		5,122		5,022
Mils Loss (Group)	6031	6,177	2649	3508	1243
Miles/Mil (Group)	6.7	8.6	15.2	17.2	32.3
% Worn (Group)	48.2	37.7	21.1	18.9	11.7
Mils Loss (Front)	2657	3180	1215	1611	539
Miles/Mil (Front)	7.6	9.5	16.5	17.8	33.5
% Worn (Front)	42.2	34.2	19.4	18.2	11.3
Mils Loss (Rear)	3373	3797	1434	1817	644
Miles/Mil (Rear)	6.0	7.1	14.0	16.6	31.2
% Worn (Rear)	54.1	41.1	22.3	19.6	12.0
Miles > Meas.	7,522		7,522		7,498(1)
Mils Loss (Group)	9912	11,151	43.18	5604	1808
Miles/Mil (Group)	6.1	8.0	13.6	16.8	32.9
% Worn (Group)(2)	79.2	61.3	34.6	29.1	13.6
Mils Loss (Front)	4256	5173	1879	2433	944
Miles/Mil (Front)	7.1	8.7	16.0	18.1	31.7
% Worn in Front(2)	34.0	28.0	15.0	13.5	7.1
Mils Loss (Rear)	5651	6172	2453	2,105	864
Miles/Mil (Rear)	5.3	7.3	12.2	15.5	34.1
% Worn in Rear(2)	45.2	33.3	19.6	19.7	6.5

(1) Due to tire failures in this group 24 miles of cross-country operation was lost during tire replacement; therefore, these figures are based on 5 tires.

(2) % worn = $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

NOT REPRODUCIBLE

SUMMARY OF TIRE TREAD WEAR (Contd.)

2. By Period (Contd.)

Tire Group	Firestone			U.S. B
	A	C		
Miles @ Meas.	10,022	10,022		10,024(1)
No. of Meas. Locations	1*	2	3	2
Mils Loss (Group)	2429	6210	7551	2549
Miles/Mil (Group)	16.5	12.9	15.9	31.5
% Worn (Group)(2)	40.5	49.5	40.8	16.0
Mils Loss (Front)	1578	2589	3394	1140
Miles/Mil (Front)	12.7	15.5	17.7	35.2
% Worn in Front(2)	26.3	20.7	18.3	7.1
Mils Loss (Rear)	851	3621	4157	1409
Miles/Mil (Rear)	23.6	11.1	14.5	28.5
% Worn in Rear(2)	14.3	28.9	22.4	8.8

Tire Group	Firestone		U.S. B(3)	Firestone D
	C			
Miles @ Meas.	12,525		12,527	2,503
No. of Meas. Locations	2	3	2	2
Mils Loss (Group)	8181	9861	3296	1357
Miles/Mil (Group)	12.2	15.2	29.9	14.8
% Worn (Group)(2)	65.3	53.2	31.0	11.9
Mils Loss (Front)	3385	4347	1414	791
Miles/Mil (Front)	14.8	17.3	35.4	12.7
% Worn in Front(2)	27.0	23.5	13.3	6.9
Mils Loss (Rear)	4796	5514	1882	566
Miles/Mil (Rear)	10.5	13.6	25.7	17.7
% Worn in Rear(2)	38.3	29.7	17.7	5.0

* Some shoulder measurement positions worn away, negating group averages for 2 and 3 locations. Figures represent crown measurements only.

(1) Figures for B Group based on 6 tires.

(2) % Worn = $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

(3) Figures for B Group based on 7 tires.

SUMMARY OF TIRE TREAD WEAR (Contd.)

2. By Period (Contd.)

Tire Group	Firestone C	U. S. B(1)	Firestone D
Miles @ Meas.	15,040	13,306	5,003
No. of Meas. Locations	1*	2	2
Mils Loss (Group)	2161	3296	2286
Miles/Mil (Group)	27.8	29.9	17.5
% Worn (Group)(2)	36.0	31.0	20.0
Mils Loss (Front)	1146	1414	1185
Miles/Mil (Front)	26.2	35.4	16.9
% Worn in Front(2)	19.1	13.3	10.4
Mils Loss (Rear)	1015	1882	1101
Miles/Mil (Rear)	29.6	25.7	18.2
% Worn in Rear(2)	16.9	17.7	9.6

Tire Group	Firestone D	U.S. E
Miles @ Meas.	7,509	2,541
No. of Meas. Locations	2	2
Mils Loss (Group)	3686	1001
Miles/Mil (Group)	16.3	20.3
% Worn (Group)(2)	32.3	8.4
Mils Loss (Front)	1724	491
Miles/Mil (Front)	17.4	20.7
% Worn in Front(2)	15.1	4.1
Mils Loss (Rear)	1962	510
Miles/Mil (Rear)	15.3	19.9
% Worn in Rear (2)	17.1	4.3

* One tire in group had shoulder measurement positions worn away, negating group averages for 2 and 3 locations. Figures represent crown measurements only.

(1) Figures are based on the performance of the seven tire samples at the last valid measurement period of each tire.

(2) % Worn = $\frac{\text{Total Mils Loss}}{\text{Total Mils Available}} \times 100$

SUMMARY OF TIRE TEMPERATURES

Heat Build-up 1st Period: After tire inflation pressures had been determined tire tread temperatures were taken for six consecutive operating days immediately after the vehicles had completed the pavement portion of the day shift operation. Pavement tire temperatures and pressures for the 2,520 miles covered by 1st period of operation are as follows:

Averages of Tread Temperatures (°F) and Tire Pressures (psig)

Tire Group	A-Firestone Control				B-U.S. Rubber Exp.				C-Firestone Exp.			
	C-1		C-2		C-3							
Vehicle	F	35	R	25	F	40	R	25	F	35	R	25
psig Cold Start												
Pave	Amb	°F	psig	°F	Cold	End	Inc	Temp	Cold	End	Inc	Temp
		(1)	(2)									
71	55	37	F	36.1	48.6	12.5	164.2	41.0	50.2	9.2	148.0	36.0
			R	26.0	36.3	10.3	177.7	26.1	34.1	8.0	155.9	25.9

- (1) At time of temperature measurement.
 (2) At cold starting time.

Heat Build-up 2nd and 3rd Periods: Pavement tire temperatures and pressures for the 5,002 miles covered by these periods of operation.

Tire Group	Group A	Group B*	Group C
Maximum Tire Temperature	230°F	211°F	224°F
Average Tire Temperature	199°F	182°F	195°F
Maximum Tire Pressure	51 psig (35 cold)	53.5 psig (40 cold)	58 psig (40 cold)
Average Tire Pressure Build-up (All Tires)	13 psig	11 psig	13 psig
Maximum Ambient	67°F	67°F	67°F
Average Ambient	60°F	60°F	60°F

* 275°F maximum at separated area.

Note: Average tread temperatures for secondary road operation are Group A, 199°F; Group B, 186°F; Group C, 189°F.

SUMMARY OF TIRE TEMPERATURES (Contd.)

Heat Build-up 4th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

Tire Group	<u>Group A</u>	<u>Group B</u>	<u>Group C</u>
Maximum Tire Temperature °F	220	245	205
Average Tire Temperature °F	198	203	199
Maximum Tire Pressure, psig	51.5 (35 cold)	56.0 (40 cold)	58.0 (40 cold)
Average Tire Pressure Build-up (All Tires) psig	13	12	14
Maximum Ambient Temperature °F	70	70	70
Average Ambient Temperature °F	62	62	62

Heat Build-up 5th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

Tire Group	<u>Group B</u>	<u>Group C</u>	<u>Group D</u>
Maximum Tire Temperature °F	265(1)	240	234
Average Tire Temperature °F	209	209	213
Maximum Tire Pressure, psig	52.0 (40 cold)	55.0 (40 cold)	52.0 (40 cold)(2)
Average Tire Pressure Build-up (All Tires) psig	11	14	12
Maximum Ambient Temperature °F	83	84	83
Average Ambient Temperature °F	82	83	74

(1) See TEST DATA, 3. Tread Temperatures & Tire Pressures.

(2) Tire pressures were originally set at 35 psig front and 25 psig rear (cold starting). On 5/18/63 at 716 total test miles tire inflation (cold starting) was increased to 40.0 psig front and 30.0 psig rear.

SUMMARY OF TIRE TEMPERATURES (Contd.)

Heat Build-up 6th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

Tire Group	<u>Group C(1)</u>	<u>Group D</u>	<u>Group E</u>
Maximum Tire Temperature °F	200	216	256
Average Tire Temperature °F	189	203	232
Maximum Tire Pressure, psig	52.5 (40 cold)	56.0 (40 cold)	54.0 (40 cold)
Average Tire Pressure Build-up (All Tires) psig	11	12	11
Maximum Ambient Temperature °F	55	84	84
Average Ambient Temperature °F	55	69	69

Heat Build-up 7th Period: Pavement tire temperatures and pressures for the 2,500 miles covered by this period of operation.

Tire Group	<u>Group D(1)</u>	<u>Group E(1)</u>
Maximum Tire Temperature °F	233	265
Average Tire Temperature °F	216	242
Maximum Tire Pressure, psig	55.0 (40 cold)	55.0 (40 cold)
Average Tire Pressure Build-up (All Tires) psig	13	12
Maximum Ambient Temperature °F	76	76
Average Ambient Temperature °F	76	76

(1) Tire temperatures were only taken once during this period.

TIRE ROLLING RESISTANCE EXPRESSED IN MILES PER GALLON

At the completion of three measurement and rotation periods wherein each tire group operated one period on each vehicle the following fuel consumption data was compiled.

	<u>Group A</u>	<u>Group B</u>	<u>Group C</u>
Miles per Gallon, Pavement	2.77	2.81	2.68
Rating	100	101	97
Miles per Gallon, Secondary and Cross-Country	1.91	2.05	1.89
Rating	100	107	99
Miles per Gallon, Total	2.18	2.30	2.14
Rating	100	106	98

DRIVER EVALUATION OF "RIDE" BY TIRE GROUPS

The first driver reaction to ride by groups was taken at the end of the 7,500 mile period; wherein each driver polled had driven each tire group on each test vehicle thereby eliminating the possibility of one vehicle influencing tire ride.

The following table indicates drivers observed ride:

Group C - Best on pavement and secondary.

Group B - Poorest on pavement and secondary.

Group A, B, C - Equal on Cross-country.

The next poll taken was at the 10,000 mile point and was a rating by the drivers of the three tire groups on the courses on which they had the most driving time. Those who placed the B Group in first place on pavement and secondary qualified the rating to the speed ranges above or below that in which lobe was developed.

Preference Driver #	Pavement							Secondary							Cross-Country						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1st	B	C	-	C	C	-	-	C	C	A	B	B	C	A	C	-	C	B	-	C	C
2nd	C	A	-	B	A	-	-	A	A	C	C	A	A	C	A	-	A	C	-	A	A
3rd	A	B	-	A	B	-	-	B	B	B	A	C	B	B	B	-	B	A	-	B	B

As tire groups were removed from test and substitute groups inserted a final observed rating was necessary covering the new groups.

The following table shows a tire Group F which was of similar construction and design as the Group B tires which were removed from test prematurely due to failures:

Preference Driver #	Pavement							Secondary							Cross-Country						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1st	DE	DE	-	DE	DE	-	-	E	E	DE	E	DE	E	-	FE	-	FE	FE	-	FE	FE
2nd	F	F	-	F	F	-	-	DF	DF	F	DF	F	DF	-	D	-	-	D	D	D	D

TEST PROGRAM

Test Courses

Pavement Operation - The first week of test operation on pavement was conducted on Highway 95A from Silver Springs to the Fort Churchill turnaround. This provided 7.1 miles of pavement operation per turnaround; however, due to high lope excitors which prevented operation of over 1800 RPM, 5th gear at the Fort Churchill end of course it was deemed necessary to eliminate the last 3.1 miles of the original course, and a new turnaround was established at the Weeks road (secondary test course) junction.

After 6540 total miles of pavement operation and 908 laps the paved course #1 from Silver Springs to Weeks turnaround on Highway 95A deteriorated to the point that a course change was required.

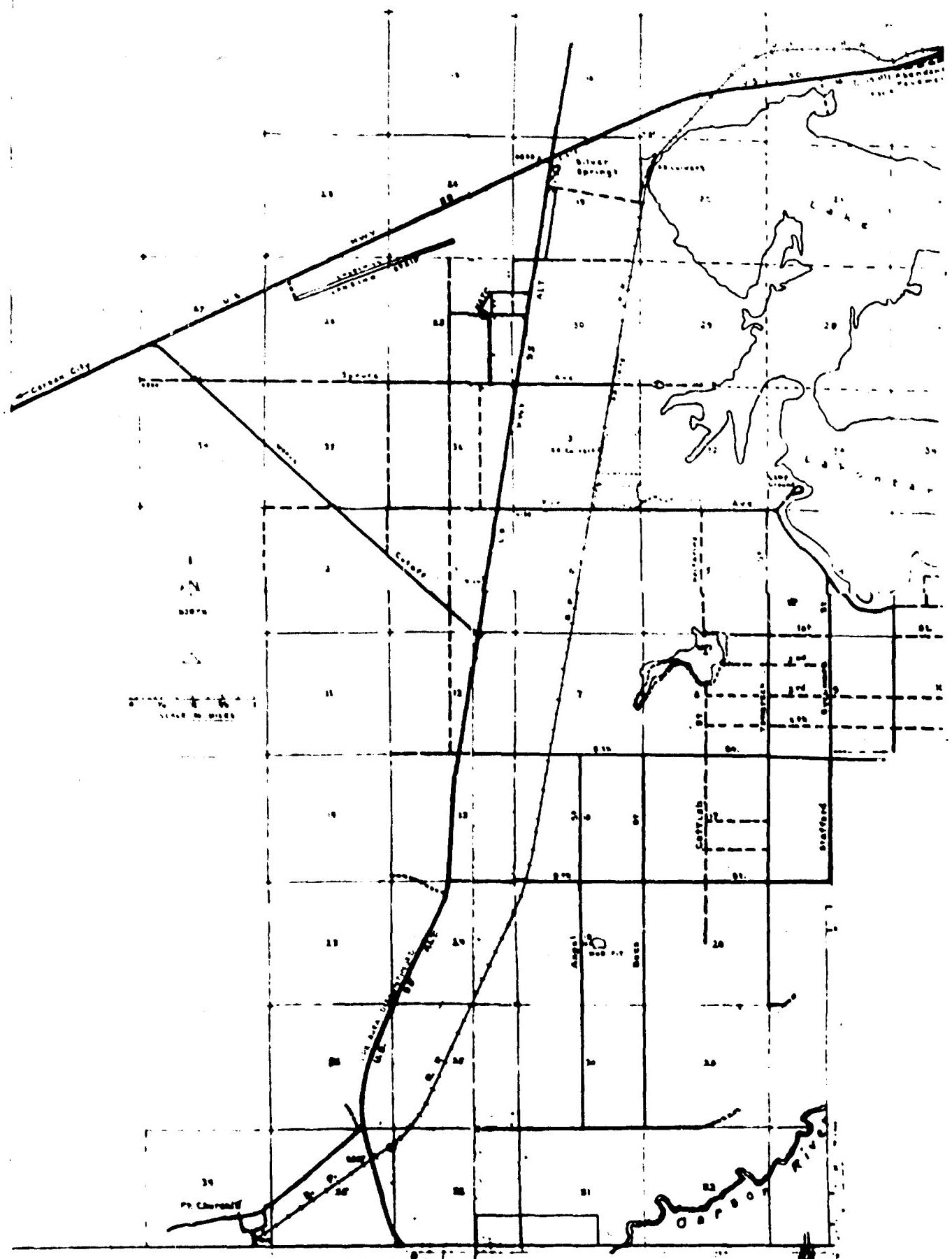
The new route (#2) on abandoned paved highway from Silver Springs to junction of Highways 50 and 95 permitted 194 miles of pavement operation per shift instead of the 104 miles per shift on test course #1, which was limited by Highway Department permit. The length of test course #2 permits an average vehicle speed of 25.8 MPH as opposed to 24.5 MPH on test course #1.

Secondary Operation - A variety of courses was used throughout the test due to the destructive forces applied by the vehicles and aggressive tire designs. As one area became a lope generator wherein maximum speed could not be sustained without undue forces on vehicle and driver, an identical test area was used to permit the destroyed course to be maintained. A noticeable improvement in course condition developed in the third 2500 mile period. The courses appeared to be "packing" a more stable surface and the cause is attributed to the considerable reduction in the aggressive lug penetration of the A and C tire groups due to wear. This same condition was also apparent on the cross-country course.

Cross-Country Operation - The same course was maintained throughout the test with the exception of the alkali flats at the north end of course which became impassable during rain storms.

The following map indicates test courses used during test with the exception of pavement course #2.

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Project 20-1-110

Upper Photograph

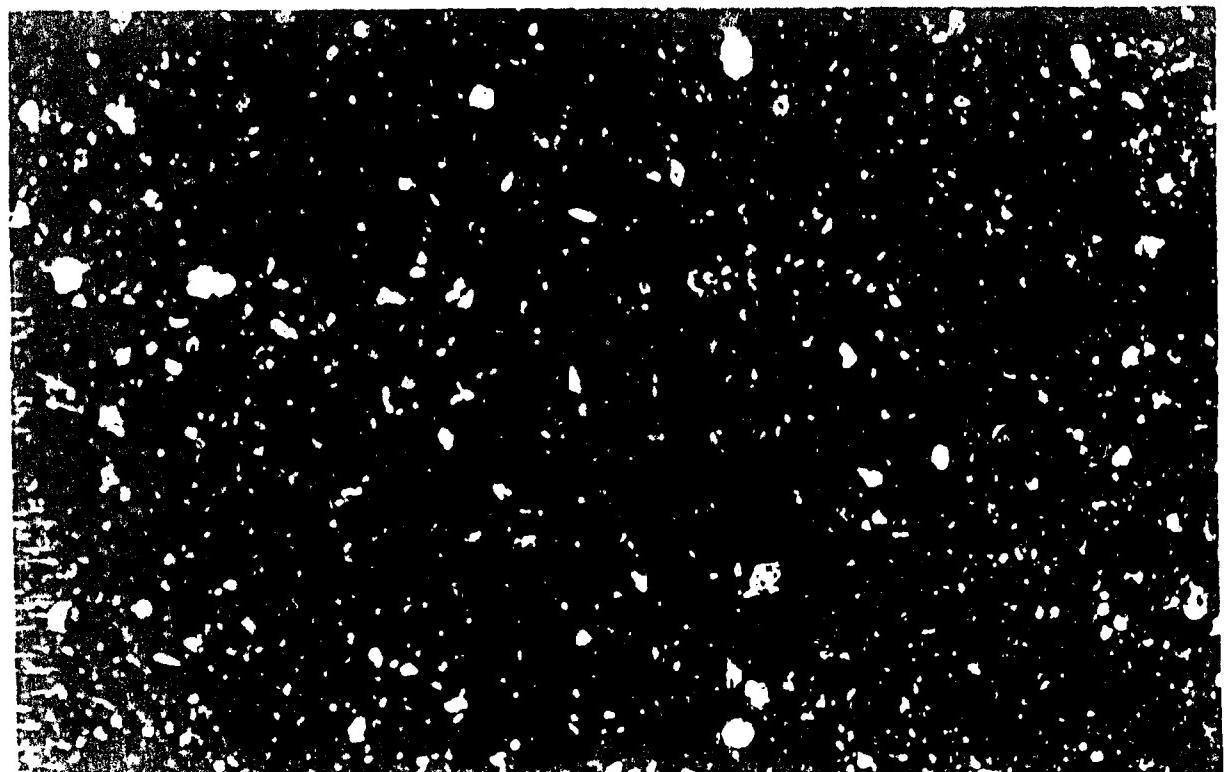
Pavement Deterioration of Course #2
Produced by the Random Cyclic Excitations of Test Vehicles

Lower Photograph

Texture of Pavement Surface Course #2

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FINAL REPORT

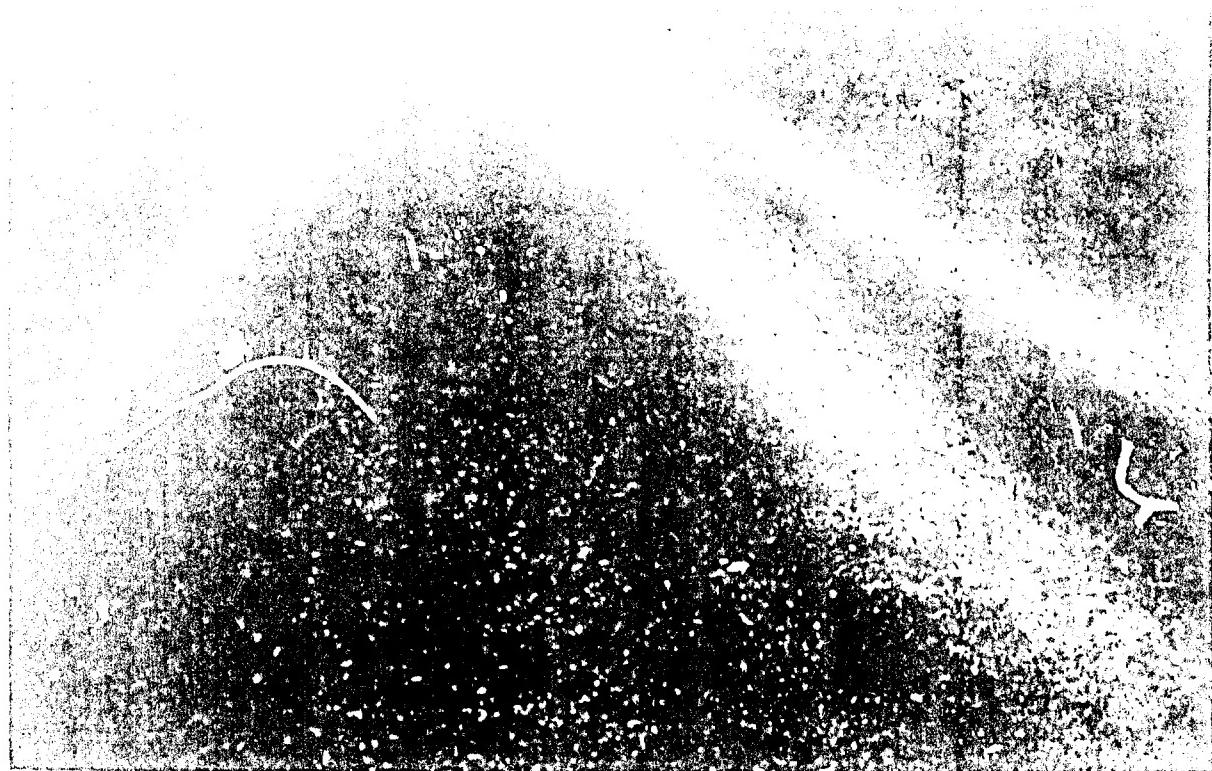
Project 20-1-110

Upper Photograph

Secondary Gravel Test Course (Weeks Road)

Lower Photograph

Cross-Country Test Course Hill Section



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TEST PROGRAM (Contd.)

Test Speeds

Cross-Country - Maximum allowed by test course and vehicle conditions.

Gravel-Secondary - Maximum allowed by test course and vehicle conditions.

Highway - Maximum allowed by test course and vehicle conditions.

Tire Break-in. Vehicle operating speeds were reduced to one-half of required test speeds for first 16 hours of operation.

Tire Inflation Pressures

At start of test, tire pressures were established for all three groups at 35 psig, front axle and 30 psig, rear axle. It was found that on pavement and secondary road operation the degree of lobe or bounce of the vehicles was so extreme that continued operation was not safe for personnel nor could the equipment withstand continued impact of the G forces involved. Tire pressures were varied in 5 psig increments, front and rear, at cold start as tabulated below, until a combination was established for each tire group that would permit safe convoy operation of the three vehicles at acceptable speeds for each type of terrain.

Tire Group	Miles at psig Settings									
	A			B			C			
	Miles	F	R	Miles	F	R	Miles	F	R	
	446	35	30	359	35	30	446	35	20	
	2074	35	25		30	30	2074	35	25	
					35	25				
				476	35	35				
					35	45				
					40	45				
					50	45				
					40	20				
				1685	40	25				

On 4 March 1963 at 3267 test miles at the beginning of 1st shift, tire inflation of the C Group tires was raised, at the manufacturer's request, by 5 psig (40 front, 30 rear) to alleviate fast shoulder wear.

When Groups D and E entered the test program the tire inflation pressures were established at 40 psig front and 30 psig rear for purposes of tread wear evaluation.

TEST PROGRAM (Contd.)

Test Vehicles

Three (3) commercial vehicles were loaded to simulate a "Goer" Tanker GVW of 70-72000 lbs. Axle load distribution was approximately 54% front and 46% rear. Test bed vehicles had equivalent torque and braking characteristics. With the exception of failed parts replacement the vehicles were maintained throughout test by the Nevada Automotive Test Center using those methods approved by the vehicle manufacturer.

Vehicle Weights

Vehicle	C-1	C-2	C-3	"Goer"(1)
Front Axle, Lbs.	38,800	39,000	38,400	38,370
Rear Axle, Lbs.	32,000	31,900	31,000	33,450
Gross Vehicle Weight	70,000	70,900	69,400	71,820
Left Rear, Lbs.	16,000	16,000	15,000	--
Right Rear, Lbs.	16,250	16,200	15,600	--
	32,250	32,200	30,600	

(1) Goer vehicle was used in engineering studies and not on tire durability tests.

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TEST PROGRAM (Contd.)

Test Mileage

Under the original test directive each group of tires was to be run 20,000 miles divided as follows:

20% - Cross-Country
40% - Secondary Gravel
40% - Highway

The following table indicates the miles accumulated and average miles per hour in each period throughout test.

Period	Groups Run	Highway Pavement		Secondary Gravel		Cross Country		Total	
		Miles	Avg. MPH	Miles	Avg. MPH	Miles	Avg. MPH	Miles	Avg. MPH
1st	A,B & C	1,000	21.9	1,000	19.1	520	9.2	2,520	16.3
2nd	A,B & C	1,000	24.4	1,002	20.7	500	8.9	2,502	17.4
3rd	A,B & C	1,000	22.7*	1,000	19.9*	500(1)	9.6	2,500	17.1
4th	A,B & C	1,000	25.7	1,000(2)	21.7	500(2)	9.8	2,500	18.3
5th	B,C & D(3)	1,003	23.5**	1,000	23.1	500	9.2	2,503	17.6
6th	B(4),C(5) D & E(6)	1,000	25.7	1,000	21.7	500	9.9	2,500	18.5
7th	D & E	1,006	26.1	1,000	23.4	500	9.7	2,506	18.8

- (1) B group tires accomplished 476 miles of cross-country due to tire failures.
- (2) B group tires accomplished 524 miles of cross-country and 1,092 miles of secondary.
- (3) D group replaced A group at start of this period due to worn smooth condition of A group.
- (4) B group terminated during this period-replaced with C group. C group accomplished 358 miles pavement, 760 miles secondary and 161 miles of cross-country for a total of 779 miles.
- (5) C group due to ride and lone study accomplished 1,015 miles pavement, 1,000 miles secondary and 500 miles cross-country for a total of 2,515 miles this period.
- (6) E group, which replaced B group, started test in the middle of 6th period and finished in the middle of 7th period. This group accomplished 1,013 miles pavement, 1,026 miles secondary and 502 miles cross-country for a total of 2,541 miles.
- * Average speed reduced; 1/2 speed, 21 hours break-in of replacement B group.
- ** Average speed reduced; 1/2 speed, 16 hours break-in of new D group tires.

TEST PROGRAM (Contd.)

Test Mileage (Contd.)

The following table indicates the test miles accumulated by each tire under each of the three conditions.

Tire Code	Highway Pave Miles	% of Total Miles	Secondary Gravel Miles	% of Total Miles	Cross- Country Miles	% of Total Miles	Total Miles
A-1	4,000	40	4,002	40	2,020	20	10,022
A-2	4,000	40	4,002	40	2,020	20	10,022
A-3	4,000	40	4,002	40	2,020	20	10,022
A-4	4,000	40	4,002	40	2,020	20	10,022
B-1	3,000	41	2,784	39	1,447	20	7,231
B-2	4,406	40	4,342	40	2,128	20	10,876
B-3	2,374	39	2,539	42	1,184	19	6,097
B-4	5,361	40	5,264	40	2,681	20	13,306
B-5	2,987	41	2,725	38	1,497	21	7,209
B-6	2,141	39	2,220	40	1,151	21	5,512
B-7	955	39	922	38	553	23	2,430
C-1	6,018	40	6,002	40	3,020	20	15,040
C-2	6,018	40	6,002	40	3,020	20	15,040
C-3	6,018	40	6,002	40	3,020	20	15,040
C-4	6,018	40	6,002	40	3,020	20	15,040
D-1	3,009	40	3,000	40	1,500	20	7,509
D-2	3,009	40	3,000	40	1,500	20	7,509
D-3	3,009	40	3,000	40	1,500	20	7,509
D-4	3,009	40	3,000	40	1,500	20	7,509
E-1	1,013	40	1,026	40	502	20	2,541
E-2	1,013	40	1,026	40	502	20	2,541
E-3	1,013	40	1,026	40	502	20	2,541
E-4	1,013	40	1,026	40	502	20	2,541

TEST PROGRAM (Contd.)

Tire Contact Areas

Contact prints were made at start of test of the right front tire of each test group at 30 psig. Additional contact prints were taken on the Group A and B tires at 15, 20 and 40 psig inflation. The gross and net contact areas for each tire and the ratio of net to gross is tabulated below.

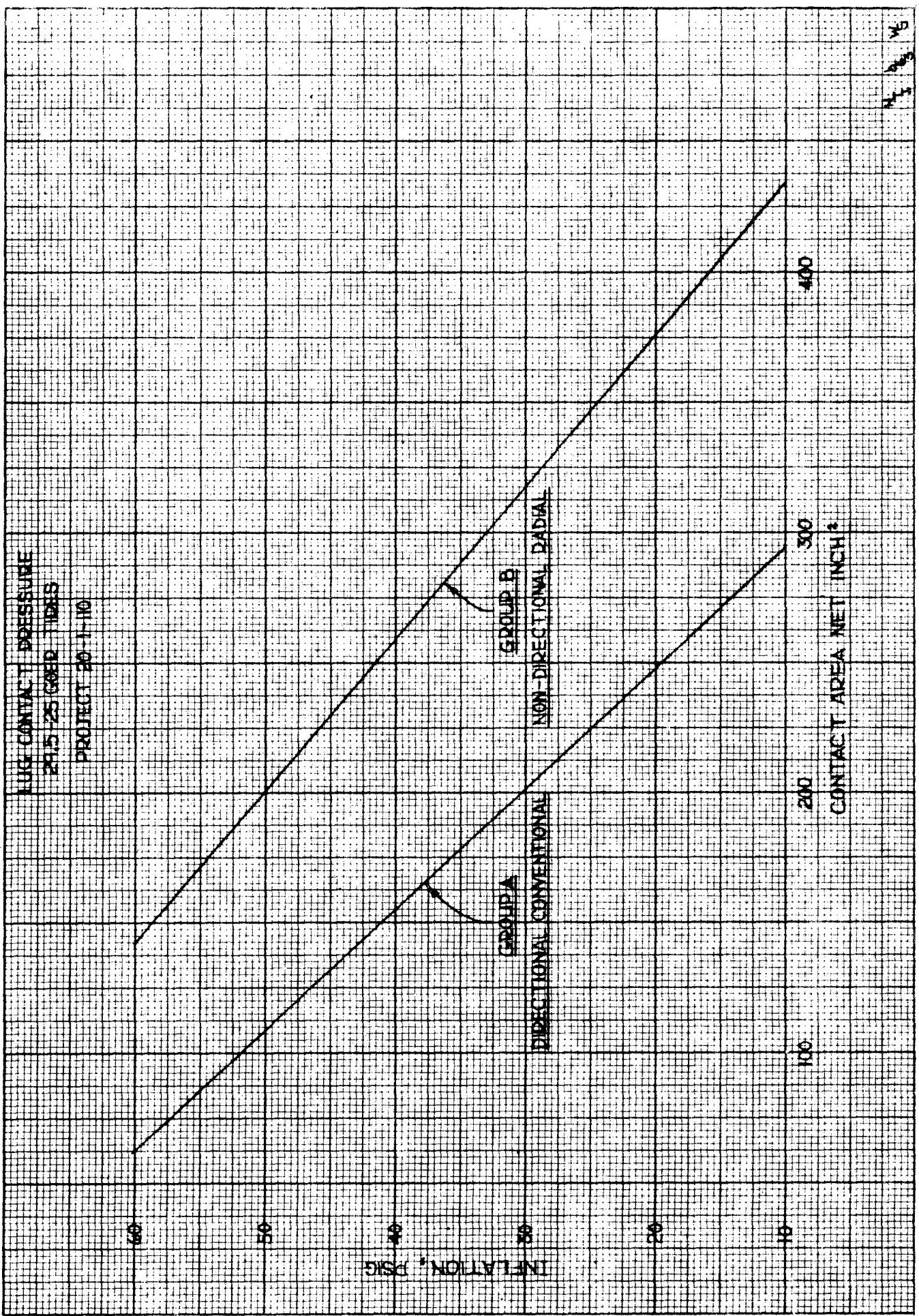
Tire Vehicle Number Tire Code	15		20		30		40	
	C-1	C-2	C-1	C-2	C-1	C-2	C-1	C-2
	A-2	B-2	A-2	B-2	A-2	B-2	A-2	B-2
Gross Area, in ²	756.3	726.2	633.7	604.4	495.7	484.3	495.7	419.6
Net Area, in ²	269.2	404.8	253.4	377.9	192.3	284.4	192.3	156.9
Ratio, Gross to Net	2.81	1.79	2.50	1.60	2.58	1.68	2.58	2.67
% of Gross	35.5	55.7	40.0	62.5	38.8	59.4	38.8	37.4
Gross Area*	25.7	26.9	30.6	32.3	39.1	40.3	38.7	46.2
Net Area*	72.1	48.2	76.6	51.6	100.9	68.6	99.8	123.6
								76.3

* Based on R.F. weight, lbs. A = 19,400 B = 19,500 C = 19,200

Group A: Firestone Super Ground Grip Goer H.D., Control

Group B: U.S. Royal Tactical M.S.

Group C: Firestone Super Ground Grip Goer Directional



TEST PROGRAM (Contd.)

Test Tire Measurements

The following measurements were taken and recorded prior to start and at every 2300-2500 miles of tire travel:

Outside Diameter

Shore Hardness - 3 places

Tread Depth - 6 places inside and outside

Tread Cutting (number and total length) minimum 2" length, 1/4" sidewall and to fabric in tread

Cross Section - 3 places

Contact Print - 30 psig on right front tire each group at start of test

Tire Rotation

<u>At End of Test Period</u>	<u>Tire Miles Accumulated</u>	<u>Rotation Schedule</u>	<u>Tire Groups Affected</u>
#1	2,520	Vehicle to vehicle-fixed wheel position.	A, B, C
#2	2,502	Diagonally front-to-rear-vehicle to vehicle.	A, B, C
#3	2,500	Vehicle to vehicle-fixed wheel position.	A, B, C
#4	2,500	Vehicle to vehicle-fixed wheel position.	B, C, D
#5	2,503	Vehicle to vehicle-fixed wheel position.	B, C, D
#6	2,500	Vehicle to vehicle-fixed wheel position.	D, E
#7	2,506		Test Terminated

Additional Tests

Due to test termination prior to the 20,000 mile limit it was considered advisable to investigate two phenomena which occurred during the test. A noticeable difference in the "ride" characteristics between tire groups was found and an observed deficiency of the non-directional radial construction tires in shallow mud. These conditions were further investigated by means of instrumentation and are covered in Appendix A "Ride Study" and Appendix B "Shallow Mud Traction".

SUMMARY OF FUEL CONSUMPTION BY TIRE GROUPS

Group A Tires

	Pavement Fuel	Off-Road Fuel	Gallons Total Fuel
1st Period, 0-2520 Miles, Vehicle C-1	361.2	782.3	1143.5
2nd Period, 2520-5022 Miles, Vehicle C-3	370.2	788.1	1158.3
3rd Period, 5022-7522 Miles, Vehicle C-2	352.0	791.6	1143.6
4th Period, 7522-10022 Miles, Vehicle C-1	360.0	723.9	1083.9
Total	1443.4	3085.9	4529.3
Miles per Gallon	2.77	1.95	2.21
Rating	100	100	100

Group B Tires

1st Period, 0-2520 Miles, Vehicle C-2	371.8	728.9	1100.7
2nd Period, 2520-5022 Miles, Vehicle C-1	362.4	745.2	1107.6
3rd Period, 5022-7498 Miles, Vehicle C-3	332.2	707.3	1039.5
4th Period, 7498-10024 Miles, Vehicle C-2	329.2	726.3	1055.5
5th Period, 10024-12527 Miles, Vehicle C-1	336.0	655.1	991.1
6th Period, 12527-13306 Miles, Vehicle C-3	120.7	216.0	336.7
Total	1852.3	3778.8	5631.1
Miles per Gallon	2.89	2.10	2.36
Rating(1)	104	108	107

Group C Tires

1st Period, 0-2520 Miles, Vehicle C-3	377.9	787.8	1165.7
2nd Period, 2520-5022 Miles Vehicle C-2	390.9	813.9	1204.8
3rd Period, 5022-7522 Miles, Vehicle C-1	349.8	789.7	1139.5
4th Period, 7522-10022 Miles, Vehicle C-3	344.8	773.0	1117.8
5th Period, 10022-12525 Miles, Vehicle C-2	356.6	686.4	1043.0
6th Period, 12525-15040 Miles, Vehicle C-1	355.4	730.4	1085.8
Total	2175.4	4581.2	6756.6
Miles per Gallon	2.77	1.97	2.23
Rating(1)	100	101	101

(1) Ratings are based on the Group A (Control) average miles per gallon consumption during the four periods they ran.

SUMMARY OF FUEL CONSUMPTION BY TIRE GROUPS (Contd.)

Group D Tires

	Gallons		
	Pavement Fuel	Off-Road Fuel	Total Fuel
5th Period, 0-2503 Miles, Vehicle C-3	352.0	682.9	1034.9
6th Period, 2503-5003 Miles, Vehicle C-2	318.2	701.1	1019.3
7th Period, 5003-7509 Miles, Vehicle C-1	334.7	703.6	1038.3
Total	1004.9	2087.6	3092.5
Miles Per Gallon	2.99	2.16	2.43
Rating(1)	108	111	110

Group E Tires

6th-7th Period, 0-2541 Miles, Vehicle C-3	333.5	739.9	1073.4
Total	333.5	739.9	1073.4
Miles per Gallon	3.04	2.07	2.37
Rating(1)	110	106	107

(1) Ratings are based on the Group A (Control) average miles per gallon consumption during the four periods they ran.

VEHICLE DURABILITY

The three Model "C" Tournapulls used in this Tire Durability Test to simulate the Army Goer Vehicle experienced a minimal parts mortality record. Other than normal vehicle service and preventative maintenance the following table indicates all failures experienced during test.

Veh. #	Date	Mileage @ Failure	Description of Failure	Cause of Failure	Disposition
C-1	3/11/63	4,799	Cable, Apron, broken.	Believed that apron limit switch was misaligned.	Replaced cable and aligned limit switch.
C-1	4/5/63	8,431	Cab Bolt, right front missing.	Unknown.	Replaced.
C-1	5/17/63	10,725	DC charging rate low.	DC Rectifiers.	Replaced.
C-1	5/27/63	12,292	DC charging rate low.	Flux bridge not properly adjusted.	Installed shims in flux bridge.
C-1	6/12/63	18,309	DC charging rate low.	Deficient coil in transformer.	Replaced trans- former.
C-2	4/5/63	8,431	Hose, Air Tank Outlet, leaking	Ruptured.	Replaced.
C-2	6/4/63	16,341	Can Arm Ball Cap, right, 2 cap screws broken.	Unknown.	Replaced.
C-2	6/4/63	16,341	Wheel Studs, left missing (Wheel came properly tightened. off bending brake drum).	Wheel Studs not missing (Wheel came properly tightened. off bending brake drum).	Replaced brake drum, tapped wheel stud holes and replaced wheel stud
C-2	6/8/63	17,609	Points, Steering Relay, left, burn- ed and not making contact.	High resistance.	Replaced left steer- ing points. Note: Points had been dressed several times prior to replacement.
C-3	3/30/63	7,522	Cable, Can Hoist, flattened and frayed.	Rubbing against can sheave side plate due to being laced incorrectly.	Replaced cable and laced correctly.
C-3	4/2/63	7,777	Hose, Rear Brake, main line broken at brass fitting.	Unknown.	Replaced.

VEHICLE DURABILITY (Contd.)

Veh. #	Date	Mileage @ Failure	Description of Failure	<u>Cause of Failure</u>		<u>Disposition</u>
C-3	4/5/63	8,517	Pin & Bearing, Apron Sheave, damaged.	Believed that apron cable forced through bearing. Welded sheave while looped.	Replaced pin and torn section of sheave side cover.	
C-3	6/8/63	17,600	Points, Steering Relay, left burned and not making contact.	High resistance.	Replaced left steer- ing points. Note: Points had been dressed several times prior to replacement.	

TEST DATA

1. TIRE MEASUREMENT SUMMARY

Best Available Copy

Voids 112.6		Miles & Loss	Miles/Mile	Worn	Worn
Per C.	Cum.	Per C.	Cum.	Per C.	Cum.
46.00					
41.65					
85	585	12.9	...	12.6	-
6.1					
7.04	1289	10.7	11.7	15.1	27.7
2.41					
17.20	7509	6.1	9.0	21.3	54.0
340					
		22.5	22.7		

TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 120MS

Project 20-1-110 Tire Group A-2 Mfg. Bagger Firestone Super Ground Grip Goer H.D.
 Date Feb. 1963 Tire Size 29.5-25 P.R. 16 Ribs Lugs Type

psig Rotation Veh. ea. 2500
 Voids 1.3 Veh. ea. 5000

Pos.	Meas.	Miles	Lbs/Cu. In.	Dk	X Sec	Profile	Surf. Inc.	Low "A"	Tread Depth	Tread Loss	Miles	Loss	Miles/Hill	Worn	Est. Hill	Hill	Central
1	RF Orig.	74.15	30.51					57	1.570	1.500	1.569		8139				
2	RF	74.53	30.83					57	1.387	1.285	1.136		2523				
3	RF	74.57	30.87					58	1.007	1.213	0.520		1535				
4	LR	74.33	30.83					58	0.380	0.072	0.608		988	1604	5.1	6.3	315 51.1
5	LR	74.33	30.83					57	1.83	1.141	2.69		492	2687	4.6	5.6	315 51.1
6	LR	74.19	30.86					57	0.824	0.72	2.59		1083	2687	4.6	5.6	315 51.1
7	LR	74.19	30.86					57	WA	WA	WA		—	—	—	—	—
8	LR	74.19	30.86					57	0.05	1.1	2.51		—	—	—	—	—

(1)

1

Mile Post.	Legs	Miles/Mile	Per Mile	Total Miles
4619	-	-	-	-
3849	-	-	-	-
761	761	9.2	-	165 -
2810	-	-	-	-
1039	1800	7.2	8.4	225 390
1999	-	-	-	-
811	2611	9.2	8.6	124 562
1316	-	-	-	-
643	3254	11.7	9.2	13.9 70.6
492	/492	/20.4	/2.4	/2.4

(2)

TIME MEASUREMENT SUMMARY

Project 20-1-110 Tire Group B-1 HSI. Descr. U.S. Royal Tactical M-3 HOPES TRAN

HODGES TRANSPORTATION INC.

TIRE MEASUREMENT SUMMARY

Project 20-1-110 : Tire Group D-2
 Date Feb. 1963 Tire size 29.5-2.6 R.R. 16 Ribs Lug Type

HONES TIRE MANUFACTURE INC.

No. 1288

U.S. Royal Tactical M.G.
 Recor: V-5
 Position V-5 to V-6
 Dist. 2000 ft.
 V-5 to V-6

Pos.	Meas. Miles	LB/In.	0 Deg X sec	Prod. 1	Sur. Prod. 2	Drift "A"	Depth "B"	Tread Prod. 3	Loss "C"	Miles/Mile	Loss
	Pepa. Cun.	Lens.	Inc. & Inc.	Prod. 1	Prod. 2	V-5	V-6	V-5	V-6	Pepa. Cun.	Loss
-2	RF ORIG	73.91	31.87	55	1319	1328	54	1347	1347		
C-2	2.520	2.520	73.62	32.37	54	1263	1242	50	2505		
			0	1.6	0.056	0.06	0	142	142	54	-
RF	2.502	5022	73.50	32.41	54	1263	1162	54	2365		
C-1			0	1.7	0.060	0.060	0	140	282	35.6	53.107
LR	24.76	74.98	73.87	52.79	55	1115	1151	2746			
C-3			0	1.6	0.082	0.11	0	99	381	39.4	53.104
LR	25.26	100.24	73.46	32.11	56	1017	1083	2100			
C-2			0	0.8	0.098	0.08	0	166	547	36.7	63.207
LR	25.52	108.76	73.52	31.94	59	848	969				
C-1			0	0.2	0	169	114				
LR	ORIG			74.03	31.56	56	1319	1320	2639		
C-1						1	1	1	1	141	23.4
LR	16.51	1651	73.90	31.90	56	1282	1216			5.3	-
C-1						0.37	104			-	-
LR	77.4	24.30	73.71	32.03	57	1185(12)	1106(2)			-	-
C-3						0.97(3)	110			-	-

OUTSIDE 1981 X

10120

10120

W.H.	Loss Per. Cum.	Miles/Hill Per. Cum.	Horn Per Cum.
4.672			
4.676	306	24.7	—
4.680	306	24.7	6.6
3.812			
3.816	812	14.8	10.9
3.820	812	14.8	17.5
3.824			
4.831	1301	15.3	11.3
4.835	1301	15.3	10.6
2.697			
6.54	1935	11.8	15.5
6.54	1935	11.8	13.7
1948			
6.91	2639	10.7	14.3
6.91	2639	10.7	15.1
1257			
746	3380	10.1	13.3
746	3380	10.1	16.1
			13.0

TIRE MEASUREMENT SUMMARY

HOOCHES TRANSPORTATION INC.

Project 20-1-110 Tire Group C-2

Form 128MS

Date Feb. 1963 Tire Size 295 - 25 P.R. 16 RIBS

Mfg. Descri. Firestone Super Ground Grip Goer

Rotation Veh. to Veh. per 2000
Frig. X Voids 1/3

Pos. Meas. Miles Lb/Gn O D* X Sec Profile Dur. On/Off Tread Depth & Tread Loss Miles Miles Miles Worn Est. M.L.

Per. Cum. Loss Inc. Inc. Low V-1 V-2 V-3 V-4 V-5 V-6 Per. Cum. Per. Cum. Per. Cum. Voids 1/3

Code Ser. Pos. Meas. Miles Lb/Gn O D* X Sec Profile Dur. On/Off Tread Depth & Tread Loss Miles Miles Miles Worn Est. M.L.

Per. Cum. Loss Inc. Inc. Low V-1 V-2 V-3 V-4 V-5 V-6 Per. Cum. Per. Cum. Per. Cum. Voids 1/3

C-2 RF Orig. 73.95 30.65 61 1575 1500 1565 3140

C-3 2520 2520 74.32 31.00 62 1454 1295 1478 2932

R.F. 24.02 5022 0.5 1.1 0.121 0.205 0.087 208 208 24.2 6.6

C-2 74.46 31.07 63 1298 1350 1225 2503

0.7 1.4 0.176 0.337 0.253 429 637 11.7 15.7 18.7 20.1

LR 2500 7522 74.26 31.10 64 929 1215 1018 1941

C-1 0.4 1.5 349 043 701 556 1193 9.0 12.6 17.1 30

LR 2500 10022 74.14 31.13 67 522 1179 843 1365

C-3 0.3 1.6 407 036 175 582 1775 8.6 11.3 18.5 56.6

LR 14.7 17.525 74.02 30.99 63 208 1065 613 821

C-2 0.1 1.1 314 114 230 544 2319 9.1 12.8 17.1

LR 25.15 15040 74.22 31.73 64 W.S. 895 368

C-1 0.4 1.9 W.S. 170 245 N.S. W.S. W.S. W.S.

LR 25.21 TERMINATED 6-1-63

Mile	Loss Cpr.	Loss Cum. Cpr.	Yards 1,2,3		Miles/Mil. PerC.	Miles/Mil. PerCum.
			Miles	Cum.		
1.0			11.3	18.3	—	89. -
2.0						
3.0						
4.0						
5.0						
6.0						
7.0						
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9.0						
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TIRE MEASUREMENT SUMMARY

HODGES TRANSPORTATION INC.

Form 120NS

Project 20-1-110 Tire Group C-3 Date Feb 1963 Tire Size 195-72

Firestone Super Ground Grip Goer

Grip Goer
Nijmegen 2500

TIRE MEASUREMENT SUMMARY

Project 20-1-110 Tire Group C-4 Mfg. Descr. U.S. Royal Tactical M.S.
 Date Feb. 1963 Tire Size 29.5-25 P.R. 16 Ribs Lugs Type

HODGES TRANSPORTATION INC.

Form 128MS

Rotation Veh. to Veh. ea. 2500
 Miles X ea. 5000
 Yards 1.3

Code Ser.	Pos.	Miles	Lbs/cu	0 Deg X Sec	Profile Inc % Inc	Drift Low "A" V-1 V-2 V-3 V-4 V-5 V-6	Tread Depth 6 Tread Loss 6	Miles Miles Miles Miles Miles Miles	Loss Loss Loss Loss Loss Loss	Per Mile Cum.	Worn Est Mi. to Bald	
C-4	R R	Orig	73.62	30.40	60	1570	1600	1560	1530	2925		
C-3	2520	2520	73.75	30.56	63	1470	1873	1455				
			0.2	0.5		0.100	0.127	0.105	705	205	24.6	-
R R	2502	5022	73.90	30.58	65	1282	1325	1150	2432			
C-2			0.4	0.6		0.188	0.048	305	493	698	10.2	14.4
L F	2500	7522	74.28	30.86	64	1042	1252	1028		2065		
C-1			0.9	1.6		240	73	127	367	1065	1316	14.1
L F	2500	10022	74.17	30.86	65	818	1195	911		1729		
C-3			0.7	1.5		224	057	112	336	1401	14.9	14.3
L F	2503	12525	73.99	30.84	62	589	1108	806		1375		
C-2			0.5	1.4		249	087	105	354	1755	14.1	14.3
L F	2515	15040	74.19	30.84	63	346	1.014	709		1055		
C-1			0.8	1.8		223	094	097	320	2015	15.7	14.5
TEST TEST TERMINATED 6-11-63												

K 2550G-2

Mile	Loss Per.	Cum. Cub.	Miles/Mil Per.	Cum. Cub.	Horn Per Cum	Horn E Per Cum
46.00						
4298						
364	332	22.8	-	72	-	
3751	813	13.9	11.3	117.3	13.9	
541						
3311						
410	1318	17.0	17.2	9.5	28.4	
2924						
393	1706	19.1	17.6	8.5	56.8	
2483						
AII	2147	17.0	17.5	9.5	46.4	
2061						
4141	2561	18.2	17.6	8.9	55.5	

TIRE INVENTORY SUMMARY

Vehicles Transportation Inc.

Name - 123001

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 | 301 | 302 | 303 | 304 | 305 | 306 | 307 | 308 | 309 | 310 | 311 | 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 | 332 | 333 | 334 | 335 | 336 | 337 | 338 | 339 | 340 | 341 | 342 | 343 | 344 | 345 | 346 | 347 | 348 | 349 | 350 | 351 | 352 | 353 | 354 | 355 | 356 | 357 | 358 | 359 | 360 | 361 | 362 | 363 | 364 | 365 | 366 | 367 | 368 | 369 | 370 | 371 | 372 | 373 | 374 | 375 | 376 | 377 | 378 | 379 | 380 | 381 | 382 | 383 | 384 | 385 | 386 | 387 | 388 | 389 | 390 | 391 | 392 | 393 | 394 | 395 | 396 | 397 | 398 | 399 | 400 | 401 | 402 | 403 | 404 | 405 | 406 | 407 | 408 | 409 | 410 | 411 | 412 | 413 | 414 | 415 | 416 | 417 | 418 | 419 | 420 | 421 | 422 | 423 | 424 | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 | 439 | 440 | 441 | 442 | 443 | 444 | 445 | 446 | 447 | 448 | 449 | 450 | 451 | 452 | 453 | 454 | 455 | 456 | 457 | 458 | 459 | 460 | 461 | 462 | 463 | 464 | 465 | 466 | 467 | 468 | 469 | 470 | 471 | 472 | 473 | 474 | 475 | 476 | 477 | 478 | 479 | 480 | 481 | 482 | 483 | 484 | 485 | 486 | 487 | 488 | 489 | 490 | 491 | 492 | 493 | 494 | 495 | 496 | 497 | 498 | 499 | 500 | 501 | 502 | 503 | 504 | 505 | 506 | 507 | 508 | 509 | 510 | 511 | 512 | 513 | 514 | 515 | 516 | 517 | 518 | 519 | 520 | 521 | 522 | 523 | 524 | 525 | 526 | 527 | 528 | 529 | 530 | 531 | 532 | 533 | 534 | 535 | 536 | 537 | 538 | 539 | 540 | 541 | 542 | 543 | 544 | 545 | 546 | 547 | 548 | 549 | 550 | 551 | 552 | 553 | 554 | 555 | 556 | 557 | 558 | 559 | 560 | 561 | 562 | 563 | 564 | 565 | 566 | 567 | 568 | 569 | 570 | 571 | 572 | 573 | 574 | 575 | 576 | 577 | 578 | 579 | 580 | 581 | 582 | 583 | 584 | 585 | 586 | 587 | 588 | 589 | 590 | 591 | 592 | 593 | 594 | 595 | 596 | 597 | 598 | 599 | 600 | 601 | 602 | 603 | 604 | 605 | 606 | 607 | 608 | 609 | 610 | 611 | 612 | 613 | 614 | 615 | 616 | 617 | 618 | 619 | 620 | 621 | 622 | 623 | 624 | 625 | 626 | 627 | 628 | 629 | 630 | 631 | 632 | 633 | 634 | 635 | 636 | 637 | 638 | 639 | 640 | 641 | 642 | 643 | 644 | 645 | 646 | 647 | 648 | 649 | 650 | 651 | 652 | 653 | 654 | 655 | 656 | 657 | 658 | 659 | 660 | 661 | 662 | 663 | 664 | 665 | 666 | 667 | 668 | 669 | 660 | 661 | 662 | 663 | 664 | 665 | 666 | 667 | 668 | 669 | 670 | 671 | 672 | 673 | 674 | 675 | 676 | 677 | 678 | 679 | 680 | 681 | 682 | 683 | 684 | 685 | 686 | 687 | 688 | 689 | 690 | 691 | 692 | 693 | 694 | 695 | 696 | 697 | 698 | 699 | 700 | 701 | 702 | 703 | 704 | 705 | 706 | 707 | 708 | 709 | 710 | 711 | 712 | 713 | 714 | 715 | 716 | 717 | 718 | 719 | 720 | 721 | 722 | 723 | 724 | 725 | 726 | 727 | 728 | 729 | 730 | 731 | 732 | 733 | 734 | 735 | 736 | 737 | 738 | 739 | 730 | 731 | 732 | 733 | 734 | 735 | 736 | 737 | 738 | 739 | 740 | 741 | 742 | 743 | 744 | 745 | 746 | 747 | 748 | 749 | 750 | 751 | 752 | 753 | 754 | 755 | 756 | 757 | 758 | 759 | 760 | 761 | 762 | 763 | 764 | 765 | 766 | 767 | 768 | 769 | 760 | 761 | 762 | 763 | 764 | 765 | 766 | 767 | 768 | 769 | 770 | 771 | 772 | 773 | 774 | 775 | 776 | 777 | 778 | 779 | 780 | 781 | 782 | 783 | 784 | 785 | 786 | 787 | 788 | 789 | 790 | 791 | 792 | 793 | 794 | 795 | 796 | 797 | 798 | 799 | 790 | 791 | 792 | 793 | 794 | 795 | 796 | 797 | 798 | 799 | 800 | 801 | 802 | 803 | 804 | 805 | 806 | 807 | 808 | 809 | 800 | 801 | 802 | 803 | 804 | 805 | 806 | 807 | 808 | 809 | 810 | 811 | 812 | 813 | 814 | 815 | 816 | 817 | 818 | 819 | 810 | 811 | 812 | 813 | 814 | 815 | 816 | 817 | 818 | 819 | 820 | 821 | 822 | 823 | 824 | 825 | 826 | 827 | 828 | 829 | 820 | 821 | 822 | 823 | 824 | 825 | 826 | 827 | 828 | 829 | 830 | 831 | 832 | 833 | 834 | 835 | 836 | 837 | 838 | 839 | 830 | 831 | 832 | 833 | 834 | 835 | 836 | 837 | 838 | 839 | 840 | 841 | 842 | 843 | 844 | 845 | 846 | 847 | 848 | 849 | 840 | 841 | 842 | 843 | 844 | 845 | 846 | 847 | 848 | 849 | 850 | 851 | 852 | 853 | 854 | 855 | 856 | 857 | 858 | 859 | 850 | 851 | 852 | 853 | 854 | 855 | 856 | 857 | 858 | 859 | 860 | 861 | 862 | 863 | 864 | 865 | 866 | 867 | 868 | 869 | 860 | 861 | 862 | 863 | 864 | 865 | 866 | 867 | 868 | 869 | 870 | 871 | 872 | 873 | 874 | 875 | 876 | 877 | 878 | 879 | 870 | 871 | 872 | 873 | 874 | 875 | 876 | 877 | 878 | 879 | 880 | 881 | 882 | 883 | 884 | 885 | 886 | 887 | 888 | 889 | 880 | 881 | 882 | 883 | 884 | 885 | 886 | 887 | 888 | 889 | 890 | 891 | 892 | 893 | 894 | 895 | 896 | 897 | 898 | 899 | 890 | 891 | 892 | 893 | 894 | 895 | 896 | 897 | 898 | 899 | 900 | 901 | 902 | 903 | 904 | 905 | 906 | 907 | 908 | 909 | 900 | 901 | 902 | 903 | 904 | 905 | 906 | 907 | 908 | 909 | 910 | 911 | 912 | 913 | 914 | 915 | 916 | 917 | 918 | 919 | 910 | 911 | 912 | 913 | 914 | 915 | 916 | 917 | 918 | 919 | 920 | 921 | 922 | 923 | 924 | 925 | 926 | 927 | 928 | 929 | 920 | 921 | 922 | 923 | 924 | 925 | 926 | 927 | 928 | 929 | 930 | 931 | 932 | 933 | 934 | 935 | 936 | 937 | 938 | 939 | 930 | 931 | 932 | 933 | 934 | 935 | 936 | 937 | 938 | 939 | 940 | 941 | 942 | 943 | 944 | 945 | 946 | 947 | 948 | 949 | 940 | 941 | 942 | 943 | 944 | 945 | 946 | 947 | 948 | 949 | 950 | 951 | 952 | 953 | 954 | 955 | 956 | 957 | 958 | 959 | 950 | 951 | 952 | 953 | 954 | 955 | 956 | 957 | 958 | 959 | 960 | 961 | 962 | 963 | 964 | 965 | 966 | 967 | 968 | 969 | 960 | 961 | 962 | 963 | 964 | 965 | 966 | 967 | 968 | 969 | 970 | 971 | 972 | 973 | 974 | 975 | 976 | 977 | 978 | 979 | 970 | 971 | 972 | 973 | 974 | 975 | 976 | 977 | 978 | 979 | 980 | 981 | 982 | 983 | 984 | 985 | 986 | 987 | 988 | 989 | 980 | 981 | 982 | 983 | 984 | 985 | 986 | 987 | 988 | 989 | 990 | 991 | 992 | 993 | 994 | 995 | 996 | 997 | 998 | 999 | 990 | 991 | 992 | 993 | 994 | 995 | 996 | 997 | 998 | 999 | 1000 | 1001 | 1002 | 1003 | 1004 | 1005 | 1006 | 1007 | 1008 | 1009 | 1000 | 1001 | 1002 | 1003 | 1004 | 1005 | 1006 | 1007 | 1008 | 1009 | 1010 | 1011 | 1012 | 1013 | 1014 | 1015 | 1016 | 1017 | 1018 | 1019 | 1010 | 1011 | 1012 | 1013 | 1014 | 1015 | 1016 | 1017 | 1018 | 1019 | 1020 | 1021 | 1022 | 1023 | 1024 | 1025 | 1026 | 1027 | 1028 | 1029 | 1020 | 1021 | 1022 | 1023 | 1024 | 1025 | 1026 | 1027 | 1028 | 1029 | 1030 | 1031 | 1032 | 1033 | 1034 | 1035 | 1036 | 1037 | 1038 | 1039 | 1030 | 1031 | 1032 | 1033 | 1034 | 1035 | 1036 | 1037 | 1038 | 1039 | 1040 | 1041 | 1042 | 1043 | 1044 | 1045 | 1046 | 1047 | 1048 | 1049 | 1040 | 1041 | 1042 | 1043 | 1044 | 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TIRE MEASUREMENT SUMMARY

Project 20-1-110 Tire Group E Mfg. Descr. U.S. DISSECTIONAL DESIGN - TRADIAL PLY CANTILEVER
 Date 6/23/1963 Tire Size 29.5-25 P.R. 14 Rib Use Type
 Pos. None
 HODGES TRANSPORTATION INC. Form 128MS

Proj. # 29-1-110. Tire Group A-1. Mgr. Descrip. Firestone Super Ground Grip Gear H.O. Central Date Feb. 1943. Tire Size 29.5-25. P.R. 16. Ribs 4. Type - pole. Reaction -

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A-1 LF 2820

VS 611 1972-13
C-1 2-2

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TIME REMAINED FROM
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CHAMBERS' HANDBOOK OF ENGLISH

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Table 1. The number of species per genus in the *Acacia* alliance.

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Weld R-Rib A-All Co-chunkout WA-Worn Away TR-To, NTR-Not so Fabric. Vg-Very Slight S-Slight M-Medium Se-Severe. Ut-Under tear

4-Sipe List ST-Sipe Tear SET-Sipe End Tear TBT-Tie Bar Tear IV-Irregular Wear TS-Tread Splice PW-Past Wear No-Flat Spot

H = H_{ext} $\vec{r} = \vec{r}_0$ V_{ext}(\vec{r}) = C-1, C-2, C-3. h = h_{ext} g_{ext} = g_{ext} + g_{ext}²/8πG.

MATERIALS & METHODS

HODGES TRANSPORTATION INC.

2

Hold Rail & All Co-Contractor H-T-Q, H-T-Tot To Fabric. W-Very slight S-Slight H-Medium Se-Severity. UT-Udeteriorate -Sipe List S-S-type rear set-Sipe rear TS-Fried Splice PMS rear PS-Flat Spot H = Hold T = Tee. Vehicles = C-1, C-2, C-3 - Inz Inside Shoulder Cut = Outside Shoulder.

Hold 2-Sid A-All co-class bout H-1-Hans (any type) HTP-Not to Patrio. Vg-Very slight g-slight h-Medium 3r-Severe. Ut-Ukdercar
-gaspipe Last St-gsipe Pkg. SRT-gsipe End Year 1971-Irregular Year 1972-Past Year RS-Flat Spot
H = Head - Vr. = Vr. Vehicles as C-1, C-2, C-3. In = Inside shoulder Out = Outside shoulder.

NOTA SOBRE

Proj. # 20-1-110 : Flock Group B-2 Higr. Decr (p. U.S. Royal Tropicbirds) Date 12/3 1963 Flock Size 295-25 P.R. 16 Blue Lure Type - - - - - Rotation Yrs. to Veh. eq. 2500

Pos.	Miles	Fold Circles	U-T	S-L	S-T	T-B-T	Scuff	I-U	T-S	P-W	P-S	Other	
												V.S. Head	In
RF	2520											1"	3 1/2" @ 4 1/2" circum. sidewall splice openings
C-2	2-4												outer, above bead, NTF 1/2" circum. sidewall splice opening, inner above bead, NTF
RF	5022												Fold openings, outside 1-2", 1-6 1/4" 1-8 1/4" F.O. Inside 1 1/2" GTE
C-1	3-15												End openings, outside 1-1", 1-7 1/2", 1-8", 1-10" TR 5 on inside 1-12" NTE. 3/4" x 3/4" Radius crack in outside sidewall II, one area of scuffing on inside sidewall.
IR	TA-6												Bedded cracks, inside sidewall 1 1/2" up from flange, 1 1/2" x 1/2" these were flings, ends exposed 1 1/2" up from flange, 1" x 1/4" & 1/2" x 1/2" tary wire plies 1 1/2" up from flange, 1 1/2" x 1/2" there wire plies, cords exposed Cut 1 1/2" x 1/2" tary wire plies cords exposed.
C-3	TA-6												S across M head out thread & heel in
IR	10024												Fold opening, length X 1/2". Break above bead, 1" TR
C-2	4-16												Fold opening, outside 1 1/2" x 3/4" TR
													Partial street from flange base to flange Partial cracks 1 1/4" x 3/4" deep
													open 7/8" wide w/ 3/8" crack extending from flange

U-Haul & All Co-Chairman Mr-Tee, MTP-Mot To Farde. W-Very slight R-Head So-severe. UT-Undercar type last ST-Slope rear SGT-Slope End rear TBT-Tie Bar rear IV-Irregular rear TB-Fast Splice FB-Fast rear FB-Flat Spot u-Haul! Tz Tee Vehicles = C-1, C-2, C-3 In = Inside shoulder, Out = Outside shoulder.

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HOSES INSPECTION SHEET

Port # 1285

TIME CONDITION & SIZING

Proj. # 20-1112
Date 7-24-68
Vane Group A
Tire Size P.R.

H.C.P.

P.R.

H.L.P.S. #	Holes	Void Creation	Type	Size	I	W	T	S	P	R	S	Other		
												1	2	
H-15	LF 12527	M-H-011	BLISTER	1/2"									LUG REPAIR UNKNOWN	"
C-1	S-29	SAW-H-011	BLISTER	1/2"									CHAMPS	
													OUT S.W. FOLD TERRACES	
													6" X 25" 2.00" T.E.	
													W.T.E. 3" T.E. 4" T.E.	
													OUT 3/4" RAD. CRACKS	
													2.00" X .050" D	
													1.50" X .050" D	
													1.50" X .050" D	
													1.50" X .050" D	
													1.50" X .050" D	
													FAULCE TRENCH 3.75"	
													OUT S.W. RADIAL	
													CRACK THROUGH	
													CAPOSS AND LINE E	
													OUT SIDE, SIDE GROOVES	
													1.00" X .050" D	
													2.00" X .050" D	
													2.50" X .050" D	
													OUT S.W. FOLD OPENINGS	
													4" X 25" T.E. 2.50" T.E.	
													3.00" T.E. 3.75" T.E.	
													20" SEC. DAY FLAMES	
													CHAINS WHEEL 12"	
													CIRC. BREAK ABOVE	
													12.5" DEEP: 3"	
													IN FLANGE CHAINING	

Void P-RD-A-11 CO-Chunkout WA-Holes Away TP-10, RTP-Rot To Fabric. VS-Very Slight S-Slight M-Medium Se-Severity. MI-Moderate S-Side L-Left R-Right T-Tight P-Past Splice R-Rest Spot

THE CONDITIONS OF SURVIVAL

Hold R-B1B A-All CO-Checkout W-Horn Away TTF-10, MTF-Not To Fabric. V8-Very Slight S-Slight H-Medium Se-Severe. UT-Undetectable
Sides Lift Strips Tear SET-Sipe Tear SET-Sipe Tear TTF-Tie Bar Tear IW-Irregular Wear TS-Fretted Splice FH-Fast Wear FG-Flat Spot
H = Head, T = Tail Joints C-1, C-2, C-3 IN = Inside Shoulder OUT = Outside Shoulder

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Proj. # 20-1110. Tire Group C-1. Mgr. Desterio. Firestone Super Ground Grip Gear
Date Feb. 1963. S150 29.5-25. P.R. 16. Rib Lug Type - psig.

Hold R-Rib A-All CO-Chankout H-Horn Army TR-To, HTP-Not To Fabric. VS-Very Slight H-Medium Se-Severity. Ut-Indicates
-Side Lift ST-Slips Tear SET-Slips End Tear TST-Tie Bar Tear IR-Irregular Hair TS-Tread Splice FG-Flat Spot
H = Heel T = Toe. Vehicles = C-1, C-2, C-3. In = Inside shoulder. Out = Outside shoulder.

proj. # 20-1-110 : Tire Group C-3 Mfr. Descrip. Firestone Super Ground Grip Gear
Tire Size 225-75-16 P.R. 16 Ribs 4 Lugs 4 Type _____
Rot. Veh. to Veh. ca. 2500

Hold R-rib A-all cover - 1/2" - 1" away
-Sipe List - S-sipes from 1/2" to 1" wide
H-Wool - C-2, C-3, C-4, C-5, C-6, C-7, C-8

THE CONDITION OF SAIL

THE CONDITION'S SUMMARY

Spec. No.	Age	Sex	Color	Size	Group	Condition
19-523	19	M.	Black	110	1	Fair

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THE POSITION I TAKE

Time spent 29.5-25. P.M. Date
proj. # 201-114 File date 29.5-25. P.M. Date
Sociedad - 201-114 Sociedad

THE CONDITION OF SLAVERY

HODGES TRANSPORTATION INC.

Form 8

Proj. # 20-1-110 Tire Group E Mfr. Descrip. U.S. DIRECTIONAL DESIGN - RADIAL PLY CONSTRUCTION
Date Feb. 1963 Tire Size 28.5-25 P.R. 16 Ribs 16 Type perg.40E-30R Rotation EACH 1500 MI.

void R-Rib A-W11 CO-Chunkout WA-Worn Away FF-To, MTF-Not To Fabric. VS-Very Slight S-Slight H-Medium Se-Severe. UT-Undetectable. -Sipe Lift ST-Sipe Tear SET-Sipe End Tear TBT-Tie Bar Tear TS-Treated Surface FMS-Fast Wear FS-Fillet Spot

Best Available Copy

PILOT DATA (Contd.)

3: Trend Temperature and Tire Pressures

Original favorable mutation generation (100 miles per snail)

TEST DATA (Contd.)

3. Tread Temperature and Tire Pressures (Contd.)

Original Pavement Course Operation (104 miles per shift) (Contd.)

Tire Group	A			B			C					
Vehicle	C-3	3/1/63(1)	3121	Vehicle	C-1	3/1/63(2)	3121	Vehicle	C-2	3/1/63(1)	3121	
Date	3/1/63(1)			Date	3/1/63(2)			Date	3/1/63(1)			
Miles				Miles				Miles				
Ambient	55°F			Ambient	54°F			Ambient	54°F			
Pavement	69°F			Pavement	68°F			Pavement	68°F			
	psig	°F	Temp	Start	psig	°F	Temp	Start	psig	°F	Temp	
	Start	Inc	Temp		Start	Inc	Temp		Start	Inc	Temp	
LF	A-1	36.0	51.0	15.0	B-1	41.0	51.5	10.5	C-1	36.0	48.5	12.5
RF	A-2	36.0	51.5	15.5	B-2	41.0	51.0	10.0	C-2	36.0	48.5	12.5
Avg. Front		36.0	51.5	15.5		41.0	51.5	10.5				
LR	A-3	26.0	39.0	13.0	B-3	26.0	35.0	9.0	C-3	26.0	35.0	9.0
RR	A-4	26.0	39.0	13.0	B-4	26.0	37.0	11.0	C-4	26.0	36.0	10.0
Avg. Rear		26.0	39.0	13.0		26.0	36.0	10.0				
Avg. Group		31.0	45.0	14.0		34.0	44.0	10.0				
Date				Date				Date				
Miles				Miles				Miles				
Ambient				Ambient				Ambient				
Pavement				Pavement				Pavement				
	3/8/63(1)				3/8/63(2)				3/8/63(1)			
	4399				4399				4399			

- (1) Taken 9" from crown center.
 (2) Taken 10 1/2" from crown center.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures

Revised Pavement Course Operation (194 miles per shift)

Tire Group	Vehicle	Date	Miles	Ambient	Pavement
C	C-1	3/19/63*	5611	60° F	78° F
B	C-3	3/19/63**	5611		
A	C-2	3/19/63*	5611		

psig		°F		psig		°F		psig		°F		psig	
Start	J	Temp	Inc	Start	J	Temp	Inc	Start	J	Temp	Inc	Start	
LF	A-4	49.0	14.0	192	B-4	40.0	50.5	10.5	172	C-4	40.0	55.0	
RF	A-3	50.0	15.0	200	B-3	40.0	51.0	11.0	200(1)	C-3	40.0	55.0	
Avg. Front	35.0	49.5	14.5	196	40.0	51.0	11.0	186	40.0	55.0	15.0	192	
LR	A-2	25.0	37.5	12.5	175	B-2	25.0	35.0	10.0	170	C-2	30.0	40.0
RR	A-1	25.0	38.0	13.0	190	B-1	25.0	34.5	9.5	165	C-1	30.0	43.0
Avg. Rear	25.0	38.0	13.0	183	25.0	35.0	10.0	168	30.0	41.5	13.0	180	
Avg. Group	30.0	43.5	13.5	189	32.5	43.0	10.5	177	35.0	48.0	13.0	186	
Date	3/21/63*			Miles	6029			Ambient	64°F			Pavement	
	72°F				6029				72°F				
psig		°F		psig		°F		psig		°F		psig	
Start	J	Temp	Inc	Start	J	Temp	Inc	Start	J	Temp	Inc	Start	
LF	A-4	35.0	50.0	15.0	230	3-4	40.0	53.5	13.5	211	C-4	41.0	58.0
RF	A-3	35.0	50.5	15.5	220	3-3	40.0	52.5	12.5	200(2)	C-3	41.0	58.0
Avg. Front	35.0	50.5	15.5	225	40.0	53.0	13.0	206	41.0	58.0	17.0	208	
LR	A-2	26.0	38.5	12.5	190	B-2	26.0	36.5	10.5	180	C-2	31.0	44.0
RR	A-1	26.0	37.0	11.0	196	B-1	26.0	36.5	10.5	185	C-1	31.0	46.0
Avg. Rear	26.0	38.0	12.0	193	26.0	36.5	10.5	183	31.0	45.0	13.0	188	
Avg. Group	30.5	44.0	13.5	209	33.0	44.5	11.5	194	36.0	51.5	15.5	199	

(1) Tire had one area of 265°F.

(2) Tire had one separated tread area at 275 of.

** * Taken 9" from crown center.
** * Taken 10 1/2" from crown center.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	A	B	C												
Vehicle	C-2	C-3	C-1												
Date	3/25/63***	3/25/63***	3/25/63***												
Miles	6408	6408	6408												
Ambient	57°F														
Pavement	70°F														
Start	psig	°F	Start												
Temp	Temp	Temp	psig												
Inc	Inc	Inc	Temp												
°F	°F	°F	psig												
Start	Temp	Temp	Start												
Temp	Inc	Temp	Temp												
Inc	Inc	Inc	psig												
°F	°F	°F	°F												
LF	A-4	35.0	48.5	13.5	--	B-4	40.0	53.0	13.0	175	C-4	40.0	56.0	16.0	--
RF	A-3	35.0	49.5	14.5	205	B-5	40.0	52.0	12.0	180	C-3	40.0	56.5	16.5	195
Avg. Front		35.0	--	--	--	40.0	52.5	12.5	178		40.0	56.5	16.5	--	
LR	A-2	25.0	37.0	12.0	--	B-2	25.0	35.5	10.5	--	C-2	30.0	42.5	12.5	--
RR	A-1	25.0	38.0	13.0	--	B-1	25.0	35.0	10.0	--	C-1	30.0	44.0	14.0	--
Avg. Rear		--	--	--	--	25.0	35.5	10.5	--		30.0	50.0	13.5	--	
Avg. Group		--	--	--	--	--	--	--	--		35.0	50.0	15.0	--	
Date				3/26/63**							3/26/63**				
Miles				6689							6689				
Ambient															
Pavement															
LF	A-4	35.0	50.0	15.0	210	B-4	40.0	53.0	13.0	199	C-4	40.0	57.5	17.5	211
RF	A-3	35.0	51.0	16.5	222	B-5	40.0	52.0	12.0	190	C-3	40.0	57.5	17.5	205
Avg. Front		35.0	50.5	15.5	216	40.0	52.5	12.5	195		40.0	57.5	17.5	208	
LR	A-2	26.0	38.0	12.0	205	B-2	25.0	36.5	11.5	186	C-2	30.0	37.5	7.5	199
RR	A-1	26.0	39.0	13.0	207	B-1	25.0	35.5	10.5	199	C-1	30.0	38.5	8.5	199
Avg. Rear		26.0	38.5	12.5	206	25.0	36.0	11.0	193		30.0	38.0	8.0	199	
Avg. Group		30.5	44.5	14.0	211	32.5	44.0	11.5	194		35.0	48.0	13.0	204	

* Taken 10 1/2" from crown center.

** Taken 5 1/4" from crown center.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	A	B	C							
Vehicle	C-2	C-3	C-1							
Date	3/26/63***	3/26/63***	3/26/63***							
Miles	6717	6731	6745							
Ambient	66°F									
Pavement	77°F									
Start	psi	°F	psi							
	Start	Temp	Start							
	Inc	Inc	Temp							
	Temp	Temp	Temp							
LF	A-4	--	B-4	--	--	203	C-4	--	--	224
RF	A-3	--	B-5	--	--	191	C-3	--	--	217
Avg. Front						197				221
LR	A-2	--	B-2	--	--	187	C-2	--	--	218
RR	A-1	--	B-1	--	--	195(1)	C-1	--	--	220
Avg. Rear						191				219
Avg. Group						194				220
Date	3/26/63**									
Miles	6745									
Ambient	67°F									
Pavement	79°F									
LF	B-4	--	--	--	--	--				
RF	B-5	--	--	--	--	--				
Avg. Front										
LR	B-2	--	--	--	--	--				185
RR	B-1	--	--	--	--	--				190(1)
Avg. Rear										188

** Taken 10 1/2" from crown center.

*** Taken 5 1/4" from crown center.

(1) Tire had one area of 230-237°F (suspected separation). The same area 14 miles later recorded a temperature of 237°F.
No separation developed.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Secondary Road Operation

Tire Group	A			B			C			
Vehicle	C-2	C-2	C-3	C-1	C-1	C-3	C-3	C-3	C-3	
Date	3/27/63***	3/27/63***	3/27/63***	3/27/63***	3/27/63***	3/27/63***	3/27/63***	3/27/63***	3/27/63***	
Miles	6923	6923	6923	6923	6923	6923	6923	6923	6923	
Ambient	63°F	63°F	63°F	63°F	63°F	63°F	63°F	63°F	63°F	
Pavement	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
Tire Pressure and Temperature Data										
	Start	psig @ Temp	°F Inc	Temp	Start	psig @ Temp	°F Inc	Temp	Start	
LF	A-4	37.5	48.0	10.5	205	B-4	42.0	52.5	10.5	190
RF	A-3	37.5	47.5	10.0	202	B-5	42.0	50.5	8.5	180
Avg. Front		37.5	48.0	10.5	204		42.0	51.5	9.5	185
LR	A-2	28.0	38.0	10.0	195	B-2	27.5	35.0	7.5	180
RR	A-1	28.0	37.5	9.5	195	B-1	27.0	34.0	7.0	192(2)
Avg. Rear		28.0	38.0	10.0	195		27.0	34.5	7.5	186
Avg. Group		33.0	43.0	10.0	199		34.5	43.0	8.5	186
									37.0	48.0
										11.0

(1) Temperatures taken this day were of secondary operation.

(2) Tire had one tread area of 215°F.

** Taken 10 1/2" from crown center.

*** Taken 5 1/4" from crown center.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	A	B	C												
Vehicle	C-1	C-2	C-3												
Date	4/4/63***	4/4/63***	4/4/63***												
Miles to Date	8106	8096	8135												
Ambient	60°F	60°F	75°F												
Pavement	70°F	75°F													
	psig	°F	°F												
	Start	J Temp	Inc												
	psig	Temp	Temp												
LF	A-4	36.0	48.0	12.0	195	B-4	41.0	53.0	12.0	205					
RF	A-3	36.0	50.0	14.0	202	B-5	41.0	51.0	10.0	188					
Avg. Front	--	--	--	199	--	--	185	--	--	204					
LR	A-2	26.0	37.0	11.0	185	B-2	26.0	37.0	11.0	218					
RR	A-1	26.0	37.0	11.0	185	B-6	26.0	36.0	10.0	205					
Avg. Rear	--	--	--	185	--	--	212	--	--	196					
Avg. Group	--	--	--	--	--	--	198	--	--	200					
Date										4/4/63					
Miles to Date										8139					
Ambient										8177					
Pavement															
	psig	°F	°F												
	Start	J Temp	Inc	psig	°F	Start	J Temp	Inc	psig	°F					
	psig	Temp	Temp	Start	J Temp	psig	°F	Inc	Start	Temp					
LF	A-4	36.0	49.0	13.0	206	B-4	41.0	53.0	12.0	185	C-4	41.0	56.0	15.0	200
RF	A-3	36.0	50.0	14.0	220	B-5	41.0	51.5	10.5	185	C-3	41.0	57.0	16.0	204
Avg. Front	--	--	--	213	--	--	185	--	--	--	--	--	--	202	
LR	A-2	26.0	38.5	12.5	210	B-2	26.0	37.5	11.5	212	C-2	31.0	42.5	11.5	197
RR	A-1	26.0	39.0	13.0	200	B-6	26.0	36.0	11.0	203	C-1	31.0	43.5	12.5	195
Avg. Rear	--	--	--	205	--	--	208	--	--	--	--	--	--	196	
Avg. Group	--	--	--	209	--	--	198	--	--	--	--	--	--	199	

** Taken 10 1/2" from crown center.

*** Taken 5 1/4" from crown center.

TEST DATA (Contd.)3. Tread Temperatures and Tire Pressures (Contd.)Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	A	B	C													
Vehicle	C-1	C-2	C-3													
Date	4/10/63***	4/10/63***	4/10/63***													
Miles to Date	9195	9185	9223													
Ambient	52°F	70°F	70°F													
Pavement	60°F	90°F	90°F													
Start	psig	°F	Start	psig	°F	Start	psig	°F	Start	psig	°F	Start	psig	°F	Temp	
	J Temp	Inc		J Temp	Inc		J Temp	Inc		J Temp	Inc		J Temp	Inc	Temp	
LF	A-4	35.0	48.0	13.0	180	B-4	40.0	54.0	14.0	208	C-4	40.0	55.0	15.0	200	
RF	A-3	35.0	48.0	13.0	183	B-5	40.0	51.0	11.0	178	C-3	40.0	56.0	16.0	192	
Avg. Front	---	---	---	182	---	---	---	193	---	---	---	---	---	---	196	
LR	A-2	26.0	37.0	11.0	183	B-2	26.0	37.0	11.0	215	C-2	30.0	42.0	12.0	200	
RR	A-1	25.0	37.5	12.5	192	B-6	26.0	36.5	10.5	245	C-1	30.0	42.5	12.5	190	
Avg. Rear	---	---	---	188	---	---	---	230	---	---	---	---	---	---	195	
Avg. Group	---	---	---	185	---	---	---	212	---	---	---	---	---	---	196	
Date	4/12/63				4/12/63				4/12/63				4/12/63			
Miles to Date	9607				9555				9555				9593			
Ambient	68°F				85°F				85°F				85°F			
Pavement																
LF	A-4	35.0	51.0	16.0	204	B-4	40.0	56.0	16.0	200	C-4	40.0	56.5	16.5	205	
RF	A-3	35.0	51.5	16.5	208	B-5	40.0	54.0	14.0	175	C-3	40.0	58.0	18.0	198	
Avg. Front	---	---	---	206	---	---	---	188	---	---	---	---	---	---	202	
LR	A-2	25.0	40.0	15.0	210	B-2	26.0	39.0	13.0	208	C-2	30.0	45.0	15.0	200	
RR	A-1	25.0	41.0	16.0	210	B-6	26.0	39.0	13.0	235	C-1	30.0	43.5	13.5	200	
Avg. Rear	---	---	---	210	---	---	---	222	---	---	---	---	---	---	200	
Avg. Group	---	---	---	208	---	---	---	205	---	---	---	---	---	---	201	

** Taken 10 1/2" from crown center.
*** Taken 5 1/4" from crown center.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	B	C	D
Vehicle	C-1	C-2	C-3
Date	5/13/63	5/13/63	5/17/63
Miles to Date	10204	10214	616
Ambient	63°F	63°F	74°F
Pavement	81°F	81°F	81°F

Tire Group	B			C			D			
	Start	psig	°F	Start	psig	°F	Start	psig	°F	
	0 Temp	Inc		0 Temp	Inc		0 Temp	Inc	Temp	
LF	B-4	40.0	52.0	12.0	190	14.0	195	14.0	195	D-4
RF	B-5	40.0	51.0	11.0	185	40.0	55.0	15.0	200	D-3
Avg. Front	--	--	--	--	188	--	--	198	--	--
LR	B-2	25.0	36.5	11.5	200	C-2	25.0	43.0	18.0	D-2
RR	B-6	25.0	36.5	11.5	205(1)	C-1	25.0	45.0	20.0	D-1
Avg. Rear	--	--	--	--	203	--	--	200	--	--
Avg. Group	--	--	--	--	195	--	--	199	--	--

Date	B	C	D
Miles to Date	10997	11072	5/21/63
Ambient	82°F	84°F	1062
Pavement	130°F	115°F	83°F

Date	B	C	D
Miles to Date	10997	11072	5/21/63
Ambient	82°F	84°F	1062
Pavement	130°F	115°F	83°F

Date	B	C	D
Miles to Date	10997	11072	5/21/63
Ambient	82°F	84°F	1062
Pavement	130°F	115°F	83°F

Date	B	C	D
Miles to Date	10997	11072	5/21/63
Ambient	82°F	84°F	1062
Pavement	130°F	115°F	83°F

Date	B	C	D
Miles to Date	10997	11072	5/21/63
Ambient	82°F	84°F	1062
Pavement	130°F	115°F	83°F

Date	B	C	D
Miles to Date	10997	11072	5/21/63
Ambient	82°F	84°F	1062
Pavement	130°F	115°F	83°F

This had a connotation on inside shoulder which recorded a temperature of 255°F.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group

B

Vehicle	C-1
Date	5/23/63
Miles to Date	11466
Ambient	71°F
Pavement	83°F

C

Vehicle	C-2
Date	5/23/63
Miles to Date	11616
Ambient	70°F
Pavement	83°F

D

Vehicle	C-3
Date	5/23/63
Miles to Date	1603
Ambient	65°F
Pavement	79°F

	psig			°F			psig			°F			psig			°F		
	Start	@ Temp	Inc	Temp	Start	@ Temp	Inc	Temp	Start	@ Temp	Inc	Temp	Start	@ Temp	Inc	Temp		
LF	3-4	40.0	52.0	12.0	215	C-4	40.0	54.0	14.0	205	D-4	40.0	50.0	10.0	207			
RF	3-5	40.0	51.5	11.5	210	C-3	40.0	54.0	14.0	200	D-3	40.0	51.0	11.0	217			
Avg. Front	--	--	--	213	--	--	--	203	--	--	--	--	--	--	--	212		
LR	B-7	25.0	36.0	11.0	200	C-2	30.0	40.0	10.0	225	D-2	30.0	40.0	10.0	195			
RR	B-6	25.0	36.5	11.5	265(1)	C-1	30.0	40.0	10.0	210	D-1	30.0	40.5	10.5	193			
Avg. Rear	--	--	--	233	--	--	--	218	--	--	--	--	--	--	194			
Avg. Group	--	--	--	223	--	--	--	210	--	--	--	--	--	--	203			

(1) Tire separated around entire inside shoulder.

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift.) (Contd.)

Tire Group	C			D			E		
Vehicle	C-1	C-2	C-3	6/6/63	6/6/63	153	3631	55°F	65°F
Date	6/6/63	6/6/63							
Miles to Date	14189								
Ambient	55°F								
Pavement	65°F								
	psig	°F	psig	Start	psig	°F	Start	psig	°F
	Temp	Inc	Temp	Temp	Temp	Inc	Temp	Temp	Temp
LF	40.0	52.5	12.5	189	D-4	40.0	50.0	10.0	212
RF	40.0	52.0	12.0	186	D-3	40.0	49.5	9.5	206
Avg. Front	--	--	--	186	--	--	--	209	
L.R.	C-2	30.0	39.5	9.5	D-2	30.0	39.0	9.0	190
R.R.	C-1	30.0	39.0	9.0	D-1	30.0	39.0	9.0	195
Avg. Rear	--	--	--	190	--	--	193	--	201
Avg. Group	--	--	--	189	--	--	--	--	221

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group	D			E		
Vehicle	C-2	C-3		C-2	C-3	
Date	6/11/63			6/11/63		
Miles to Date				1199		
Ambient	68°F					
Pavement	87°F					
	Start	psig	°F	Start	psig	°F
	0	Temp	Inc	0	Temp	Inc
LF	D-4	40.0	54.0	14.0	18.7	E-3
RF	D-3	40.0	53.5	13.5	19.2	E-4
Avg. Front	--	--	--	19.0	--	--
LR	D-2	30.0	41.0	11.0	20.3	E-1
RR	D-1	30.0	41.0	11.0	19.8	E-2
Avg. Rear	--	--	--	20.1	--	--
Avg. Group	--	--	--	19.5	--	--
Date	6/12/63			6/12/63		
Miles to Date	4995			1635		
Ambient	84°F					
Pavement	97°F					
	Start	psig	°F	Start	psig	°F
	0	Temp	Inc	0	Temp	Inc
LF	D-4	40.0	56.0	16.0	21.6	E-3
RF	D-3	40.0	55.0	15.0	21.2	E-4
Avg. Front	--	--	--	21.4	--	--
LR	D-2	30.0	43.0	13.0	21.5	E-1
RR	D-1	30.0	43.0	13.0	21.0	E-2
Avg. Rear	--	--	--	21.3	--	--
Avg. Group	--	--	--	21.3	--	--

TEST DATA (Contd.)

3. Tread Temperatures and Tire Pressures (Contd.)

Revised Pavement Course Operation (194 miles per shift) (Contd.)

Tire Group

Vehicle

Date

Miles to Date

Ambient

76°F
Pavement 92°F

D

C-1

6/17/63

5887

E

C-3

6/17/63

2487

	psig	°F	psig	°F	
	Start	Inc	Start	Inc	Temp
LF	D-4	40.0	53.0	13.0	217
RF	D-3	40.0	55.0	15.0	233
Avg. Front		--	--	225	
LR	D-2	30.0	41.5	11.5	209
RR	D-1	30.0	42.5	12.5	205
Avg. Rear		--	--	207	
Avg. Group		--	--	216	
					245
					242

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FINAL REPORT

Project 20-1-110

Appendix A - "Ride" Study

and

Appendix B - Shallow Mud Traction

July 1963

Nevada Automotive Test Center
A Division of Hodges Transportation Inc.
Box 234 Carson City, Nevada

APPENDIX A

FINAL REPORT

Project 20-1-110

**Comparison of Vehicle "Ride"
as Influenced By Vehicle Configuration
and Tire Design**

July 1963

**Nevada Automotive Test Center
A Division of Hodges Transportation Inc.
Box 234 Carson City, Nevada**

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APPENDIX A

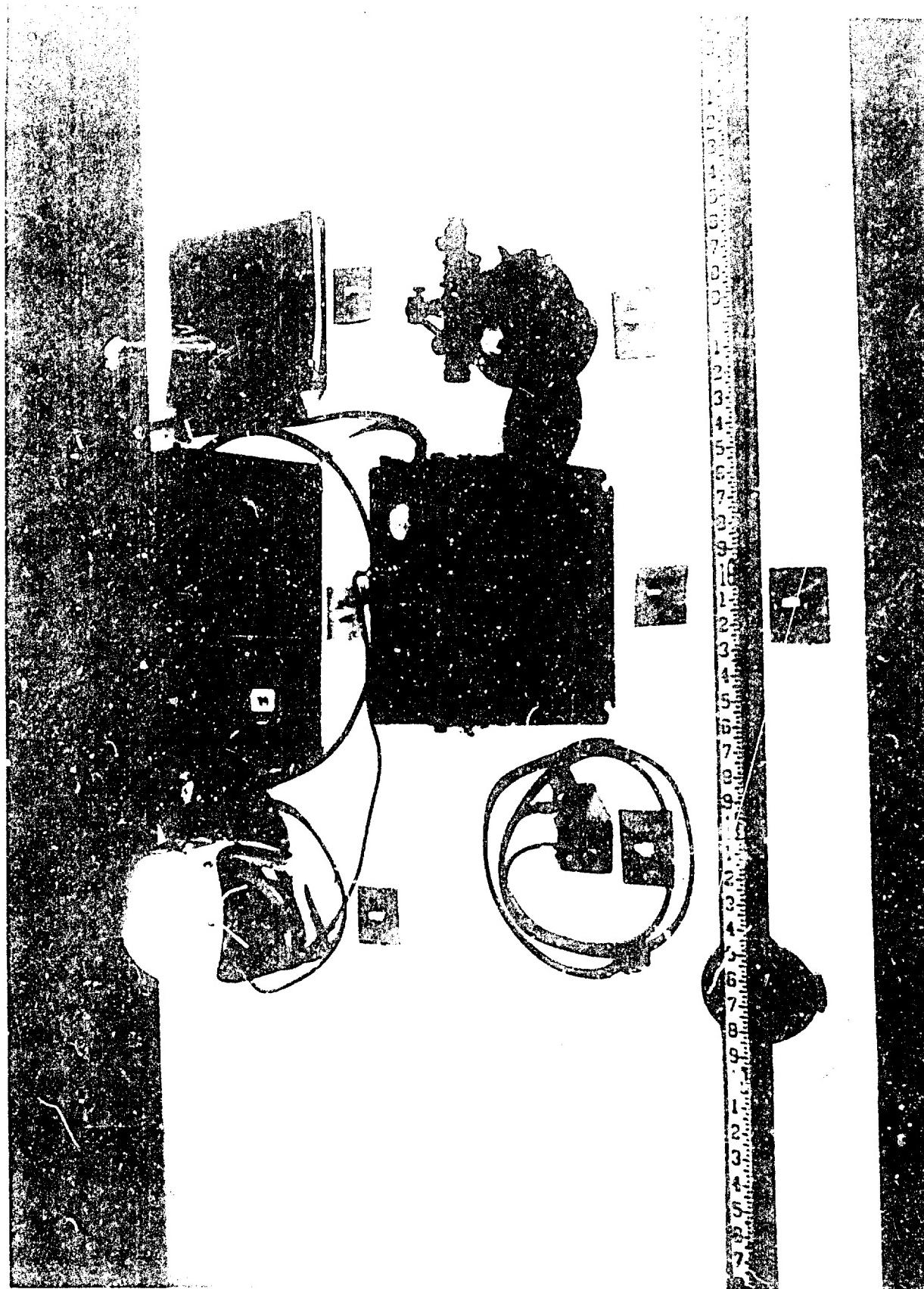
FINAL REPORT

Project 20-1-110

This Photograph shows the Recording and Measurement Equipment Necessary to conduct this "Ride" Study.

1. General Radio Model 761A Vibration, Displacement and Velocity Meter.
2. Sunbeam Strip Chart Recorder (not used during test due to the forces acting on the recording system and absence of suitable mount; therefore, visual readings were recorded directly from the vibration meter).
3. "Lock-on" helmet with Vibration Meter Pickup used in measuring drivers' reaction to ride.
4. Vibration Meter Pickup used in measuring vehicles' reaction to ride.
5. Stadia Rod used in measuring course profile.
6. Transit used in conjunction with Stadia Rod.
7. Notebook of instrument manuals.

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APPENDIX A

HISTORY

Shortly after the inception of the tire tread wear and durability evaluation, Project 20-1-110, it became obvious that the "ride" severity of the "test bed" Model "C" Tournapull on the pavement, secondary and cross-country courses was limiting the desired vehicle speed. Adjustment of test tire inflation pressures was made to improve pavement "ride", but by necessity secondary and cross-country terrain was negotiated at the pressure established as the most reasonable optimum for pavement.

The tire manufacturers' representatives and the vehicle manufacturer's representative had previously observed certain "ride" characteristics of the ATAC "Goer" Tanker unit which were influenced differently by the performance of non-directional radial ply tires (Group B) when compared with the directional conventional construction tires (Group A). These observed differences were not confirmed by the performance of the Model "C" Tournapull "test beds" mounted on similar tires. The seriousness of the Model "C" Tournapull's "ride" problem was climaxed by the failure of the paved test course, Route #1, due in part to the high dynamic loads imposed by the tires during periods of random cyclic excitation which developed progressively larger areas of pavement deterioration.

The secondary road courses also suffered under these dynamic loads but the absence of public traffic on these roads provided the operators a certain latitude in avoiding known exciters.

On pavement the most sensitive tires in terms of "lope" generation were the non-directional radial ply, Group B. On secondary road surfaces the Group B tires were difficult to excite, but once excited, rate of decay was exceptionally slow compared with the directional conventional tires (Groups A and C). In cross-country the non-directional radial ply Group B tires could negotiate "rough" single impacts at a higher rate of speed than Groups A or C, but if a combination of three or more closely spaced impacts was present, the Group B tires would achieve a compound amplitude quickly reaching the intolerable limit for both driver and vehicle. The Group A and C, on the contrary, would transmit a higher initial "jerk" force but would require a considerably greater number of closely spaced impacts before an intolerable compound reaction resulted.

As the Group A and C tires became severely worn and the directional tread elements were significantly reduced, the operator's subjective "ride" experience improved, whereas the Group B tires reacted essentially without change throughout the test.

TEST PLAN

Establishing the cause of the adverse "ride" reaction of the non-directional radial ply (Group B) tires required a subjective "ride" comparison of the non-directional radial ply tires (Group F) originally used on the "Goer" Tanker. At the conclusion of the tire tread wear and durability study a set of Group F tires formerly applied to the "Goer" Tanker were mounted on one of the Model "C" Tournapull "test beds". Although a direct comparison with the Group B tires was impossible, a complete lap of each test course with the Group F tires indicated little, if any, change in the operator's subjective "ride" experience. This comparative evaluation, however crude, identified Groups B and F as developing similar ride characteristics; consequently, this process of elimination suggested a significant difference in the "ride" reaction of the "Goer" Tanker compared with the Model "C" Tournapull "test beds". To permit a dimensional analysis of the "ride" differences between "Goer" and Model "C" Tournapull, all comparative "ride" reactions were determined by measurements expressed in terms of a "ride" index value.

Each test course was carefully surveyed for particularly significant sections which would support high density test use without change. Upon location of the test course the Group F and the Group A tires at two different inflation pressures were used to establish a constant test speed based on subjective reaction while the vibration meter simultaneously identified the significant excitors and the area of maximum effect. The inflation pressures selected for the "Ride" Study were a compromise based on different pressure build-up rates for the various tires tested as well as different build-up rates for cross-country and pavement-secondary operation. The selection of 50 psig front and 40 psig rear represented a mean pressure build-up for pavement and secondary roads from a cold starting pressure of 35-40 psig front and 25-30 psig rear. The selection of 40 psig front and 30 psig rear for all three "ride" test courses represented a mean pressure build-up for pavement and secondary roads from a cold starting pressure of 25-30 psig front and 18-23 psig rear, and for cross-country a cold starting pressure of 30-35 psig front and 20-25 psig rear.

A "Goer" Tanker was available for this comparative "ride" study and was loaded with sufficient liquid ballast to provide a "Goer" GVW equal to its rated GVW with a 5,000 gallon gasoline load (71820#). The Model "C" Tournapull was loaded at a comparable weight and weight distribution.

Two test areas on pavement, one "smooth" and one "rough"; three test areas on secondary, one which was visually "smooth" but generated a significant Model "C" Tournapull "lope", one "smooth" and one "rough"; and one test area in cross-country identified as "rough" represented six significantly different surface conditions, five of which were negotiated at two inflation pressures, while the sixth was the single cross-country area to be negotiated at only one inflation pressure.

CONCLUSIONS

The "Goer" Tanker at rated load provides a significantly better "ride" than the Model "C" Tournapull on rough pavement and secondary road surfaces regardless of tire influence.

In cross-country terrain both vehicles are sharply sensitive to tire differences; specifically, the "Goer" equipped with radial ply non-directional tires is equally as good as the Model "C" Tournapull equipped with directional conventional tires. Inversely when the tire groups are reversed, the "ride" of both vehicles is equally severe.

The natural frequency of both vehicles is sensitive to the type of tires applied. On the Model "C" Tournapull "test bed" the directional conventional tires (Group A) develop 2.15 cycles per second; the non-directional radial ply tires (Group F) develop 1.73-1.80 cycles per second; the non-directional conventional construction tires (Group D) develop 2.00-2.16 cycles per second; and directional radial ply tires (Group E) develop 1.80 cycles per second at 50-40 psig front and 40-30 psig rear. At 30 psig front and 20 psig rear the natural frequency is reduced to 1.50 cycles per second for Groups F and E and 1.80 for Group D.

When the Group A is applied to the "Goer" the natural frequency at 50-40 psig front and 40-30 psig rear is reduced from 1.80 cycles per second to 1.67-1.70 cycles per second. Under the same conditions the Group F natural frequency is reduced from 1.80 cycles per second to 1.70 cycles per second.

Under the eleven test conditions established for the "ride" study the "Goer" vehicle equipped with the directional conventional tires (Group A) exceeded the human fatigue limit (Ride Index 0.89) on three conditions and the vehicle fatigue limit (Ride Index 1.91) on one of these three conditions. The "Goer" vehicle equipped with the non-directional radial ply tires (Group F) exceeded the human and vehicle fatigue limit in cross-country only.

A similar comparison of the influence of tire groups on the Model "C" Tournapull found the Group A tires exceeding the human fatigue limit on five conditions of which two exceeded the vehicle fatigue limit and the Group F tires exceeding the human fatigue limit on six conditions of which three exceeded the vehicle fatigue limit.

The non-directional conventional tires (Group D) and the directional radial ply tires (Group E) were only evaluated on the Model "C" Tournapull. The Group D tires exceeded the human fatigue limit on seven of the eleven conditions of which four exceeded the vehicle fatigue limit. The Group E tires exceeded the human fatigue limit on four of the eleven conditions of which three exceeded the vehicle fatigue limit.

CONCLUSIONS (Contd.)

The subjective "ride" impressions of operators during the tread wear and durability study as well as the operator during the "ride" study confirmed the measured results in terms of "good" and "bad" but without any apparent "feel" for degree of severity once "bad" was reached.

At the beginning of the "ride" study it was necessary to evaluate a subjective "ride" impression expressed by the Model "C" Tournapull operators that one particular type of seat cushion was the most comfortable. By measuring the operator's displacement as influenced by the seat cushion, it was determined that the reduced depth cushion was more comfortable and provided less amplification of input displacement than the deep cushion, consequently the shallow cushion was used throughout the "ride" study.

The non-directional conventional construction tires (Group D) required a speed reduction of 0.6 miles per hour on the rough pavement condition and 1.6 miles per hour on the rough secondary road condition due to the violent reaction of the Model "C" Tournapull at the pre-established test speed.

When driver "ride" measurements are compared with Model "C" Tournapull "ride" measurements under identical conditions, we find the driver generally suffers a proportionately greater increase in amplitude with increased input severity.

Where significant excitors exist, a small increase in vehicle speed (i.e., 1.2 MPH) amplifies Model "C" Tournapull "ride" reaction as much as six times for the Group D tires, four times for the Group F tires and three times for the Group E tires. The Group A tires on the "Goer" indicated no significant increase under the same conditions.

TEST RESULTS

Measured "Ride" Reaction

The results of this study are given on the following pages in tabular and graph form.

Table I summarizes the result of the "Ride" Study comparing tire group performance in terms of vehicle "ride" index values. A "ride" index value of 0.89 is defined as being the acceptable limit of human fatigue for continuous operation.

Table II summarizes the result of the "Ride" Study comparing the performance of the Model "C" Tournapull with the "Goer" Tanker, in terms of vehicle "ride" index value. A "ride" index of 1.91 is defined as being the acceptable limit of vehicle fatigue for continuous operation (approximately 0.8 to 0.9 G). (See GRAPh LEGEND, Figures 1 and 2).

Figure 1 illustrates the "ride" comparison on pavement of each tire group on the Model "C" Tournapull at two inflation pressures.

Figure 2 illustrates the "ride" comparison on pavement of the "Goer" versus the Model "C" Tournapull with Group A and F tires at two inflation pressures.

Figure 3 illustrates the "ride" comparison of each tire group on the Model "C" Tournapull at two inflation pressures under three conditions of secondary road surfaces.

Figure 4 illustrates the "ride" comparison under three conditions of secondary road surfaces of the "Goer" versus the Model "C" Tournapull vehicle with Group A and F tires at two inflation pressures.

Figure 5 illustrates the "ride" comparison of the Model "C" Tournapull versus driver reaction under three conditions of secondary road surfaces on Group F and D tires at two inflation pressures.

Figure 6 illustrates the same conditions as Figure 5 but with Group A and E tires.

Figure 7 illustrates the "ride" comparison of driver on deep versus shallow seat cushion under three conditions of secondary road surfaces using Group D tires on the Model "C" Tournapull at one inflation pressure.

Measurements (Contd.)

Measured "Ride" Reaction (Contd.)

Figure 6 illustrates the "ride" comparison on cross-country as influenced by the vehicles as well as the tires at one inflation pressure.

Figure 7 illustrates the "ride" comparison of Groups D, E and F under two conditions of pavement at two test speeds on the Model "C" Tournapull and the Group A tires on the "Roar" vehicle at one inflation pressure.

TABLE I

Condition	Tire Groups							
	A	B	C	D	E	F	G	H
Front Tire, psic	40	50	40	50	40	50	40	50
Rear Tire, psic	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>	<u>30</u>	<u>40</u>
<u>"Ride" Index</u>								
Pavement								
#1, smooth	0.35	0.68	0.51	0.50	0.60	0.30	0.50	0.31
#2, rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.60	<u>4.60*</u>	<u>2.00*</u>	<u>2.15*</u>	0.72
Secondary								
#1, smooth	0.54	0.65	0.50	<u>1.20</u>	0.44	<u>0.98</u>	0.22	0.54
#2, smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.24	<u>1.90</u>	0.28	<u>1.40</u>
#3, rough	0.85	<u>2.38*</u>	<u>0.92</u>	<u>2.90*</u>	<u>0.91</u>	<u>4.30*</u>	0.75	<u>2.00*</u>
Cross-Country								
Rough	<u>2.7*</u>	--	<u>6.2*</u>	--	<u>10.2*</u>	--	<u>5.8*</u>	--

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

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TEST RESULTS (Contd.)

TABLE II

Vehicle Tire Group <u>Condition</u>	Vehicle "Ride" Indices							
	Model "C" Tournapull				"Goer" Tanker			
	A	F	A	F	A	F		
Inflation, Front, psig	40	50	40	50	40	50	40	50
Inflation, Rear, psig	30	<u>40</u>	30	40	30	40	30	40
<u>"Ride" Index</u>								
Pavement								
#1, Smooth	0.35	0.68	0.51	0.50	0.22	0.27	0.31	0.29
#2, Rough	<u>1.10</u>	<u>1.10</u>	<u>2.30*</u>	0.80	0.57	0.65	0.80	0.75
Secondary								
#1, Smooth	0.54	0.66	0.50	<u>1.20</u>	0.22	0.56	0.20	0.18
#2, Smooth	0.52	<u>1.21</u>	0.37	<u>1.40</u>	0.20	<u>1.40</u>	0.35	0.38
#3, Rough	0.85	<u>2.38*</u>	<u>0.92</u>	<u>2.90*</u>	0.51	<u>0.90</u>	0.55	0.62
Cross-Country								
Rough	<u>2.70*</u>	--	<u>6.20*</u>	--	<u>5.70*</u>	--	<u>2.90*</u>	--

	Comparison of Mean Vehicle "Ride" Indices					
	Pavement		Secondary		Cross-Country	
	Smooth	Rough	Smooth	Smooth	Rough	Rough
Goer @ 40-30 psig	0.27	0.69	0.21	0.28	0.53	<u>4.30*</u>
"C" Pull @ 40-30 psig	0.43	<u>1.70</u>	0.52	0.45	0.89	<u>4.45*</u>
Goer @ 50-40 psig	0.28	0.78	0.37	0.59	0.78	--
"C" Pull @ 50-40 psig	0.59	<u>0.95</u>	<u>0.33</u>	<u>1.31</u>	<u>2.64*</u>	--

Underlined values are in excess of acceptable human fatigue limits for continuous operation.

(*) Asterisked values are in excess of acceptable human and vehicle fatigue limits for continuous operation.

GRAPH LEGEND

Figures 1 and 2

Speed: 27.6 Miles Per Hour

Key	Description
	40 - 50 = 50 PSI Front Tires 40 PSI Rear Tires
	40 - 30 = 40 PSI Front Tires 30 PSI Rear Tires
Cond. 1	= Smooth Road
Cond. 2	= Rough Road
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
<u>"Vehicle Limit"</u>	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*
Ride Index	= Displacement (inches) X frequency (cycles per second)

Note: Speed reduced to 27.0 MPH on D Group, Condition 2, due to D Group's adverse reaction.

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

"Data Comparison On Divergent &
Convergent Spaced And Horizontal
Magnetization Patterns"

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A. J. S. Giese

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Intensity

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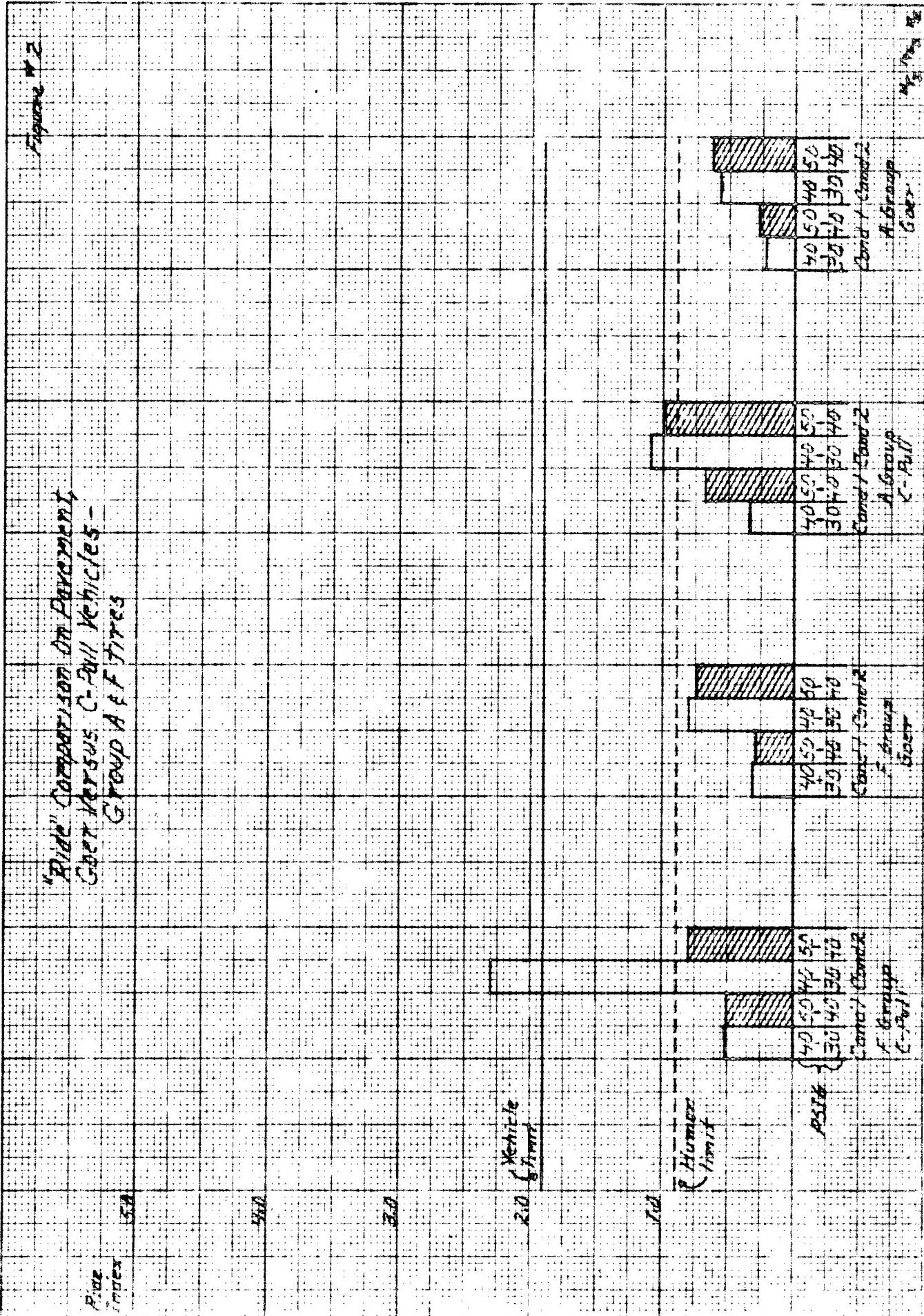
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GRAPH LEGEND

Figures 3 and 4

Speed: 22.6 Miles Per Hour

Key	Description
	= 50 PSI Front Tires 40 PSI Rear Tires
	= 40 PSI Front Tires 30 PSI Rear Tires
Cond. 1	= 100 Foot Smooth Road Section Acting as Lope Generator
Cond. 2	= 100 Foot Smooth Road Section
Cond. 3	= 100 Foot Road Section with Three Exciters Followed by a Smooth Road Section
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
"Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

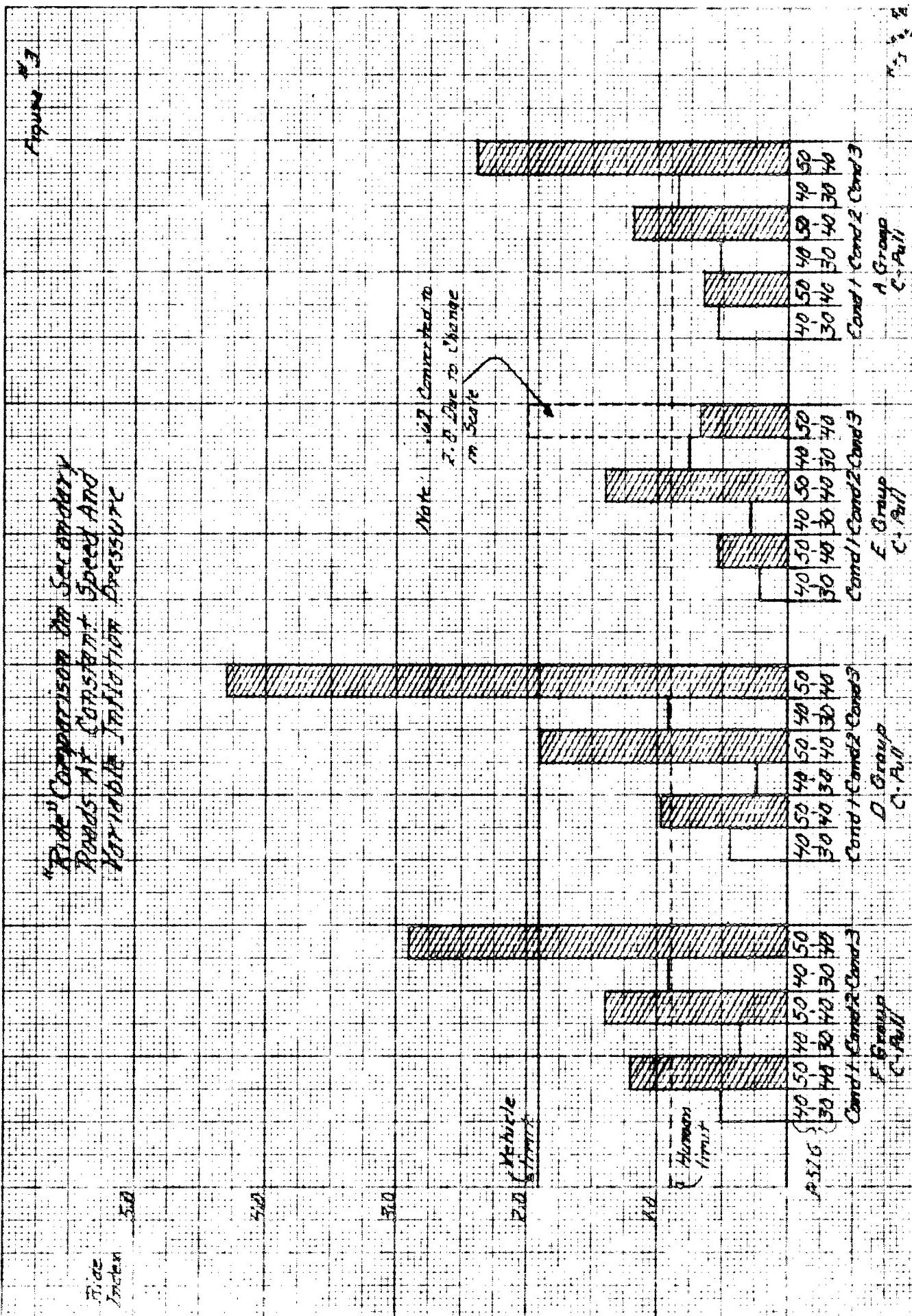
Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

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GRAPH LEGEND

Figures 5 and 6

Speed: 22.6 Miles Per Hour

Key	Description
	= Vehicle Reaction-40 PSI Front Tires 30 PSI Rear Tires
	= Driver Reaction-40 PSI Front Tires 30 PSI Rear Tires
	= Vehicle Reaction-50 PSI Front Tires 40 PSI Rear Tires
	= Driver Reaction-50 PSI Front Tires 40 PSI Rear Tires
Cond. 1	= 100 Foot Smooth Road Section Acting as Lope Generator
Cond. 2	= 100 Foot Smooth Road Section
Cond. 3	= 100 Foot Road Section with Three Shallow Exciters Followed by a Smooth Road Section
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
"Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

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GRAPH LEGEND

Figure 2

Speed: 22.6 Miles Per Hour

40 PSI Front, 30 PSI Rear

Key	Description
	Cond. 1 = 100 Foot Smooth Road Section Acting as Lope Generator
	Cond. 2 = 100 Foot Smooth Road Section
	Cond. 3 = 100 Foot Road Section with Three Shallow Exciters Followed by a Smooth Road Section
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
— "Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

Note: All #3 Conditions are at 21.0 MPH or 1.6 MPH below specified speed due to D Group's adverse reaction.

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

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2500 - 300 - 300 = 2000
2000 - 1000 = 1000
1000 - 500 = 500
500 - 200 = 300

GRAPH LEGEND

Figure 8

Speed: 7.4 Miles Per Hour

40 PSI Front, 30 PSI Rear

Course Involved 3 Depressions and 3 Lifts

<u>Key</u>	<u>Description</u>
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
— "Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

Fig. 1. Comparison for the effect of
cross country at constant speed
with the transition distance

Brake
distance 130

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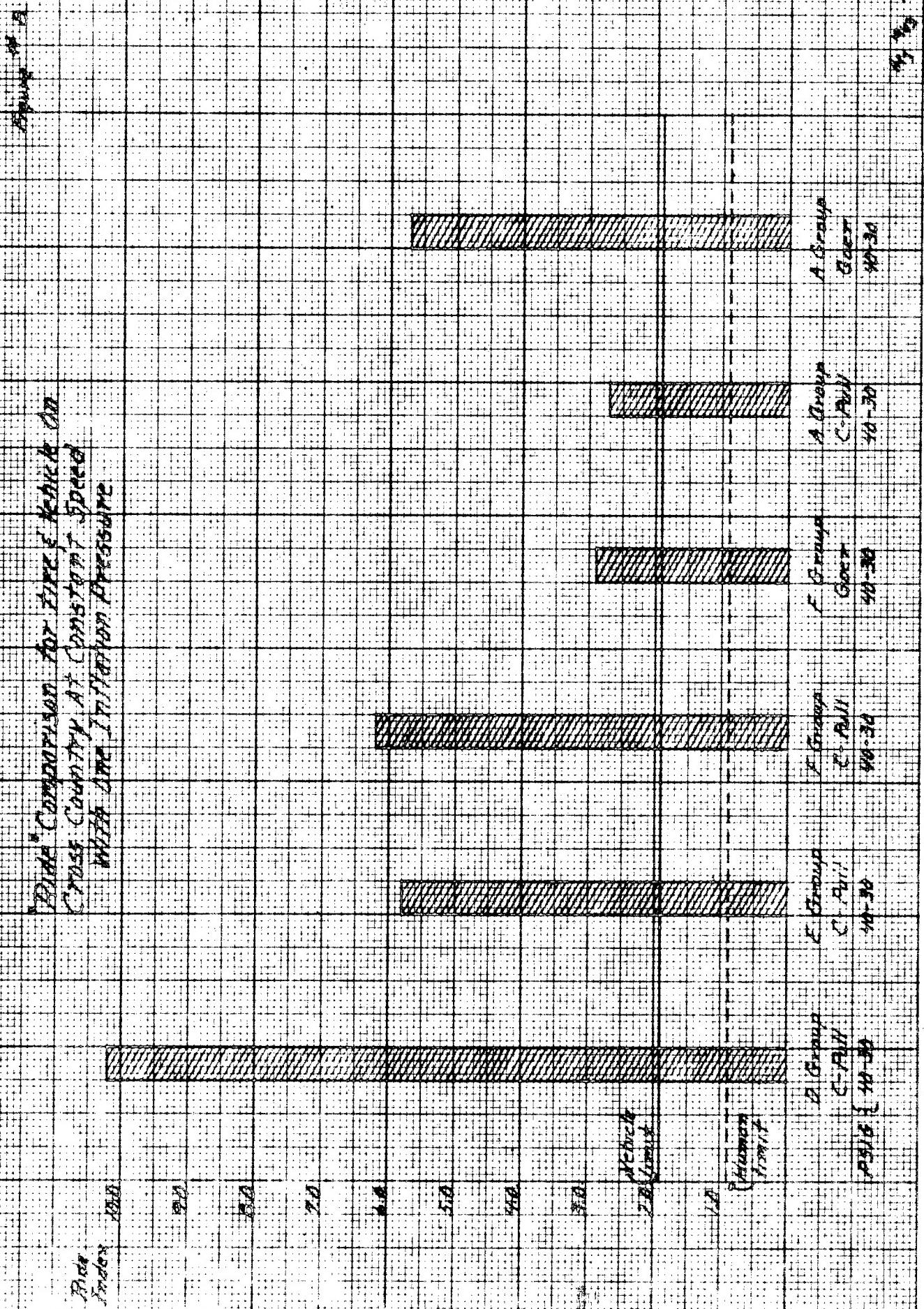
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GRAPH LEGEND

Figure 9

40 PSI Front, 30 PSI Rear

<u>Key</u>	<u>Description</u>
	= 26.4 Miles Per Hour
	= 27.6 Miles Per Hour
Cond. 1	= Smooth Road
Cond. 2	= Rough Road
----- "Human Limit"	= Acceptable "Human" Continuous Fatigue Limit of .89* (Ride Index)
— "Vehicle Limit"	= Acceptable Vehicle Continuous Fatigue Limit of 1.91 (Ride Index) as Interpreted from Goldman's "Intolerable" Limit*

* Goldman, D.E., A Review of Subjective Responses to Vibratory Motion of the Human Body in the Frequency Range 1 to 70 Cycles per Second Report No. 1, Project NM 004001, Naval Medical Research Institute, March 16, 1948.

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TEST RESULTS (Contd.)

Subjective "Ride" Reaction

The following table reflects the operator's "ride" impressions of the two tire Groups D and E which were added to the tread wear and durability test and the tire Group F which was of similar construction and design as the Group B tires.

Preference Driver #	Pavement							Secondary							Cross-Country						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1st	DE	DE	-	DE	DE	-	-	E	E	DE	E	DE	E	-	FE	-	FE	FE	-	FE	FE
2nd	F	F	-	F	F	-	-	DF	DF	F	DF	F	DF	-	D	-	-	D	D	D	D

TEST PROGRAM

Test Courses

Pavement - A portion of Nevada Automotive Test Center's highway pavement test course #2 (abandoned U.S. Highway 50) was chosen to provide two test sections. Test section #1 was smooth, whereas test section #2 (See Road Profile of Pavement Test Section Figures #1 and #2) was of rolling contour featuring two major excitors.

Secondary - A portion of Nevada Automotive Test Center's secondary test course having a compaction of 300+ PSI was chosen to provide three test sections. Test section #1 was a visually smooth surface which generated "lope" in the Model "C" Tournapull units. Test section #2 was smooth surface creating no lope. Test section #3 (See Road Profile of Secondary Test Section #3 Figures #3 and #4) was of rolling contour featuring three major excitors.

Cross-Country - A section of Nevada Automotive Test Center's cross-country test course was chosen as a severe but not extreme condition. This test section provided three excitors (See Road Profile of Cross-Country Test Section Figure #5).

$$\begin{aligned} \text{Scale} &= 1'' = 1.5' \\ \text{Horz} &= 1'' = 4' \end{aligned}$$

Front Elevation of Poured Test Section #2
Talladega Valley Inter.
Project No. 4

12' White Oak

Grade Line

133' E. C.S.

235'

23' Depth

2nd section 2' center

Front 12'

Front 20' 6" from front center

Front 12' from front center

Front 40' ft

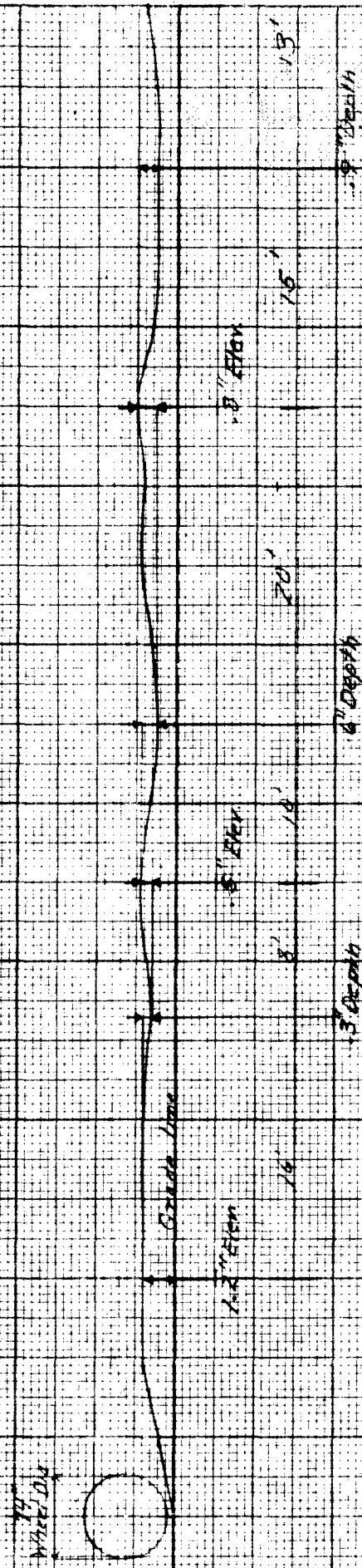
231-260-14

500/e
Front 1" = 15'
Rear 1" = 4'

Scallop
Test 116
10/22/10

Engage

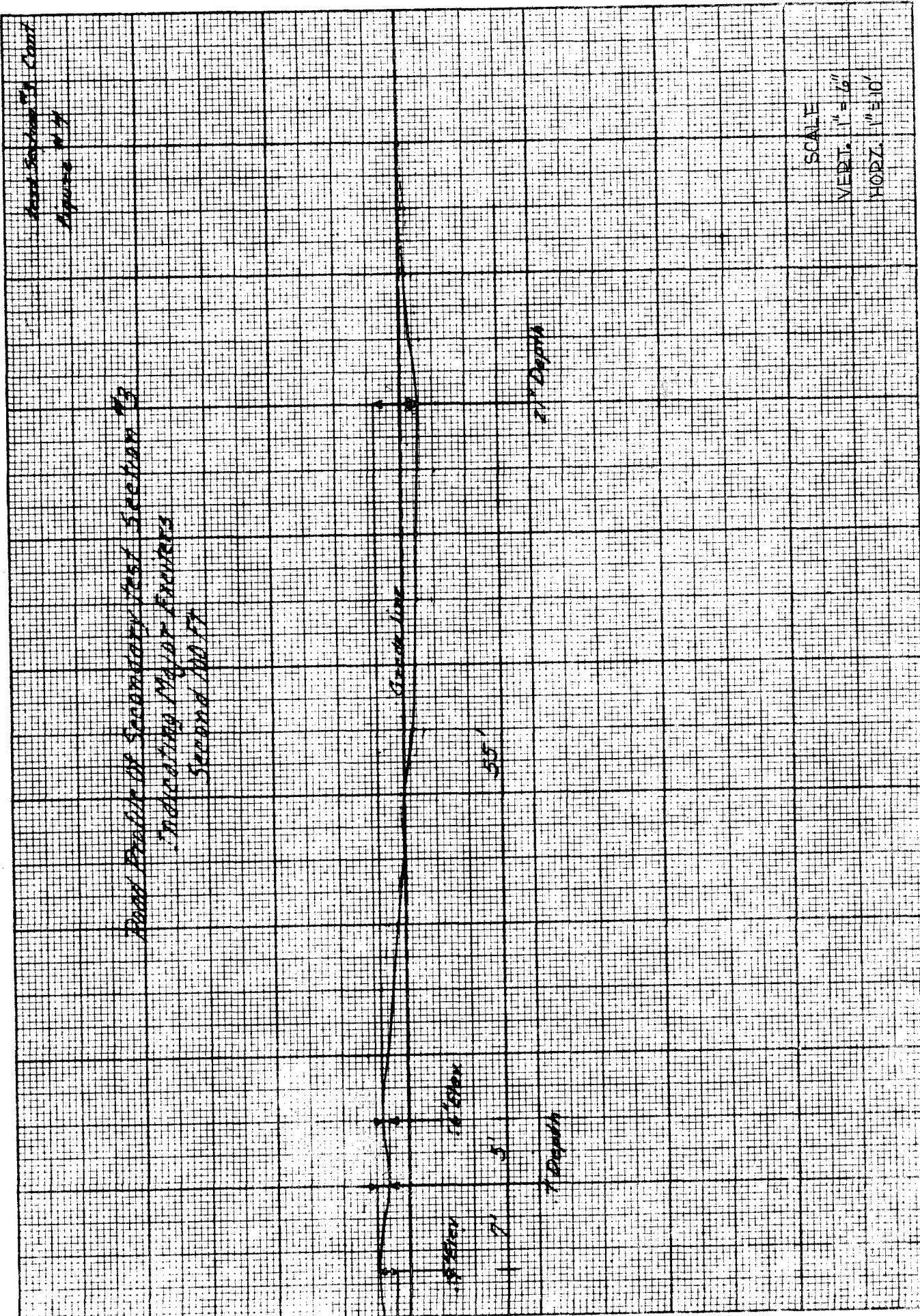
Front 2nd gear Secondary Test Section 13
Front 1st gear Major Circles

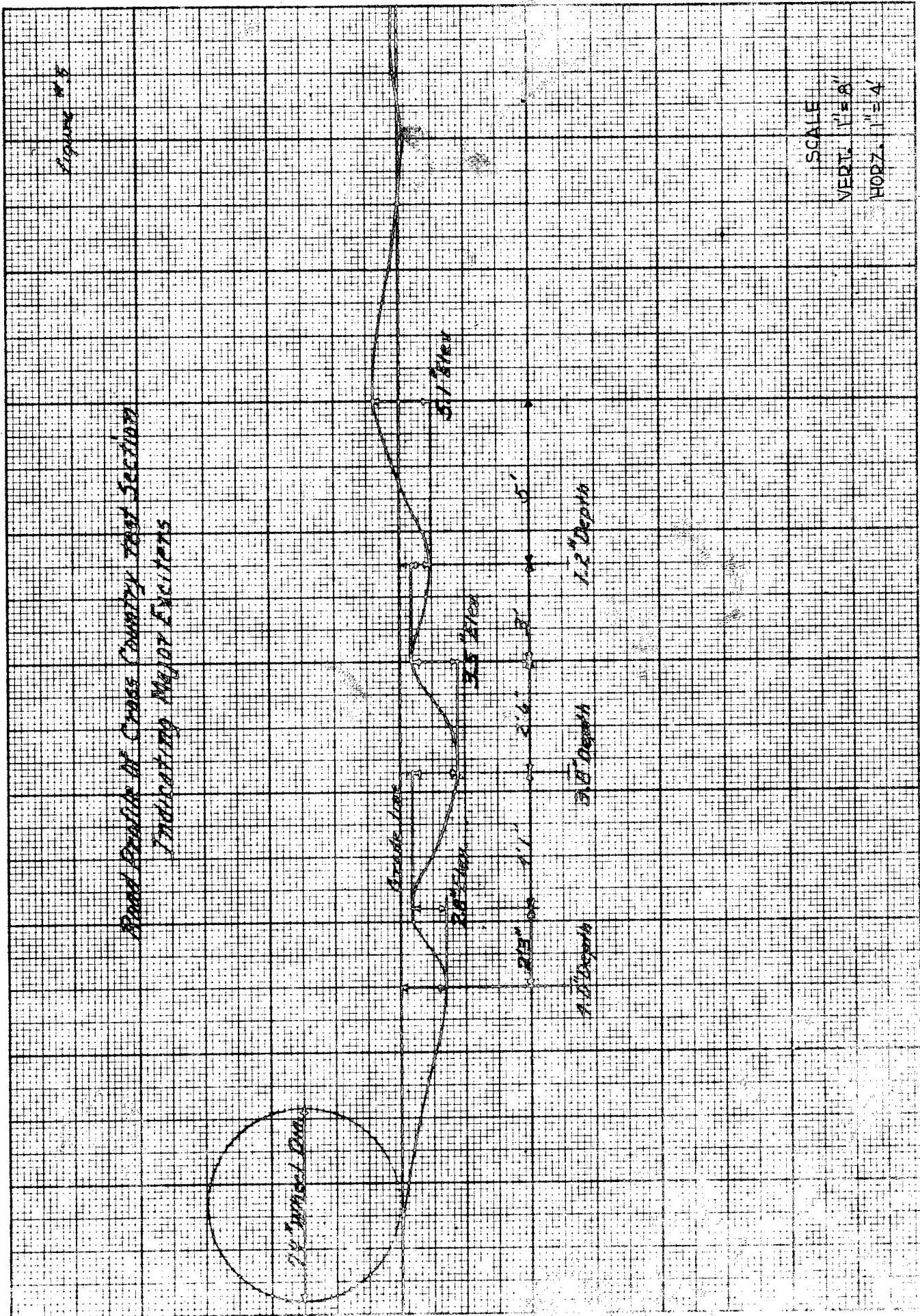


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TEST PROGRAM (Contd.)

Test Vehicles

One Model "C" Tournapull

One "Goer" Tanker XM438E2

Test Tires

Two of the five groups which ran on the tread wear and durability evaluation (Groups D and E) were subjected to the "ride" study. The Groups A, B and C tires were not available but a Group A and a Group F were substituted and were of similar design and construction as the Group A and Group B tires. Thus the following test groups were subjected to the "ride" evaluation:

Group A, Conventional construction directional tread.

Group D, Conventional construction non-directional tread.

Group E, Radial ply construction directional tread.

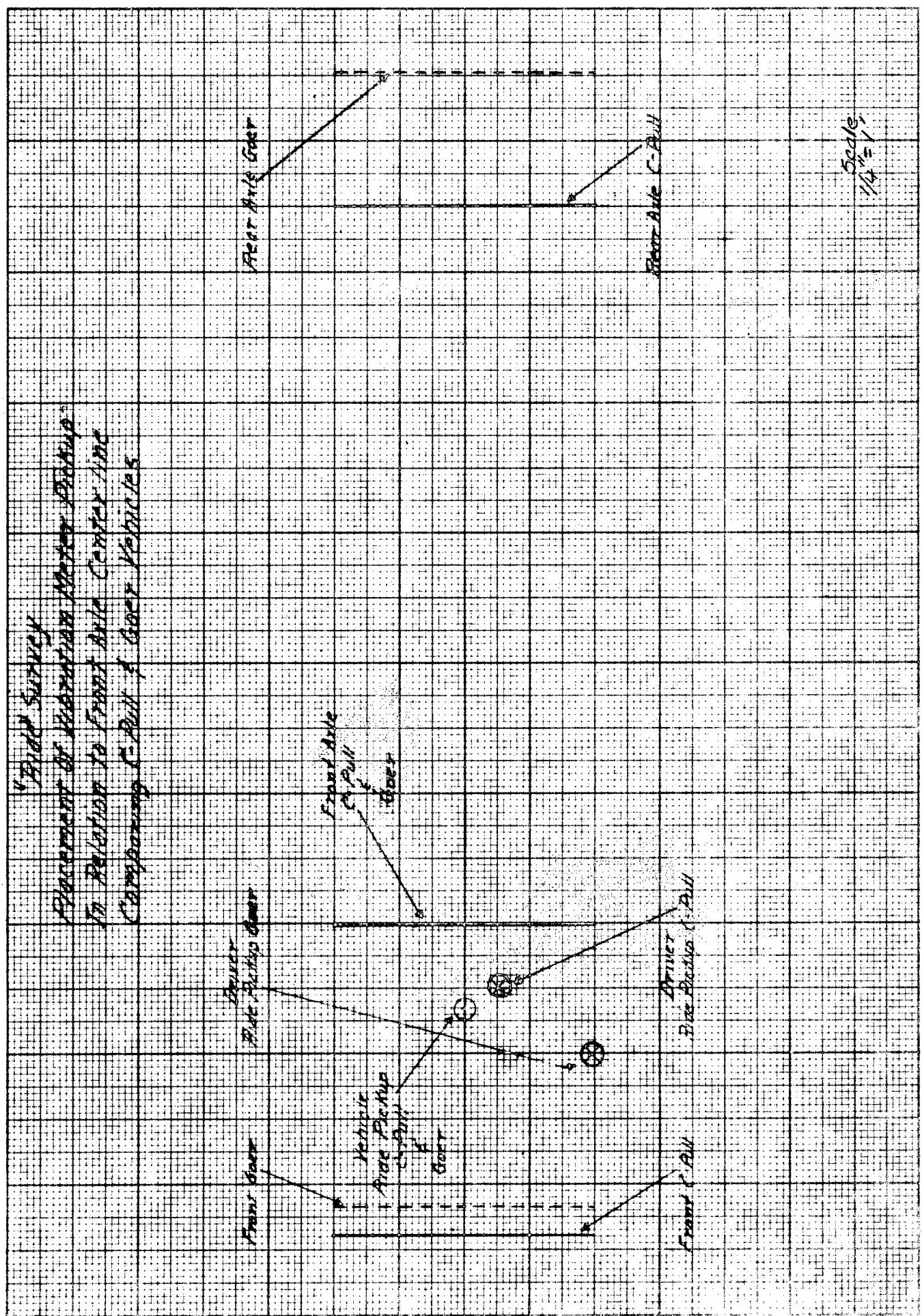
Group F, Radial ply construction non-directional tread.

Test Procedure

To evaluate comparative vehicle "ride" a vibration pickup location common to both Model "C" Tournapull and the "Goer" Tanker vehicle was chosen (approximately on centerline and 2 feet 7 inches ahead of the front axle). An average of two runs plus reruns as required were made at each inflation pressure, under each test condition, for the three test courses, on each group of test tires.

To evaluate driver reaction to vehicle "ride" a lock-on helmet was instrumented with a vibration meter pickup.

The following schematic shows the location of the Vibration Meter Pickups relative to the front axle position of both the Model "C" Tournapull and the "Goer" Tanker vehicle.



APPENDIX B

FINAL REPORT

Project 20-1-110

Shallow Mud Traction of Tire Groups A and B Type

July 1963

Nevada Automotive Test Center
A Division of Hodges Transportation Inc.
Box 234 Carson City, Nevada

AIRPORT X-3

FINAL REPORT

Project ZD-1-110

Upper Photograph

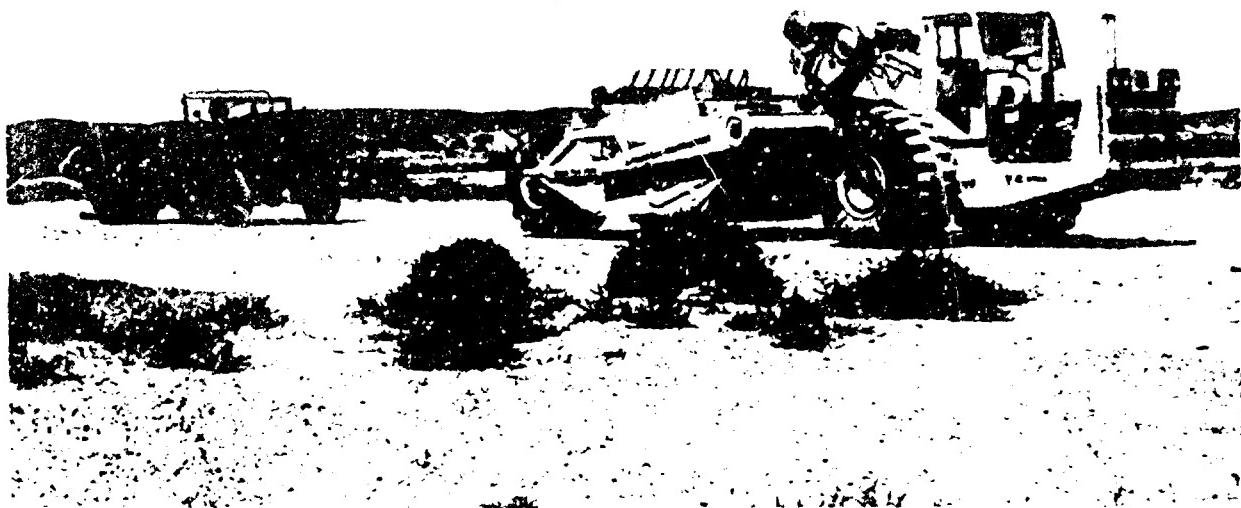
Mud Test Area

Lower Photograph

Mud Test Equipment Convoy

NOT REPRODUCIBLE

Best Available Copy



APPENDIX A

HISTORY

Shortly after the inception of the tire tread wear and durability evaluation, Project 20-1-110, it became obvious that the "ride" severity of the "test bed" Model "C" Tournapull on the pavement, secondary and cross-country courses was limiting the desired vehicle speed. Adjustment of test tire inflation pressures was made to improve pavement "ride", but by necessity secondary and cross-country terrain was negotiated at the pressure established as the most reasonable optimum for pavement.

The tire manufacturers' representatives and the vehicle manufacturer's representative had previously observed certain "ride" characteristics of the ATAC "Goer" Tanker unit which were influenced differently by the performance of non-directional radial ply tires (Group B) when compared with the directional conventional construction tires (Group A). These observed differences were not confirmed by the performance of the Model "C" Tournapull "test beds" mounted on similar tires. The seriousness of the Model "C" Tournapull's "ride" problem was climaxed by the failure of the paved test course, Route #1, due in part to the high dynamic loads imposed by the tires during periods of random cyclic excitation which developed progressively larger areas of pavement deterioration.

The secondary road courses also suffered under these dynamic loads but the absence of public traffic on these roads provided the operators a certain latitude in avoiding known excitors.

On pavement the most sensitive tires in terms of "lope" generation were the non-directional radial ply, Group B. On secondary road surfaces the Group B tires were difficult to excite, but once excited, rate of decay was exceptionally slow compared with the directional conventional tires (Groups A and C). In cross-country the non-directional radial ply Group B tires could negotiate "rough" single impacts at a higher rate of speed than Groups A or C, but if a combination of three or more closely spaced impacts was present, the Group B tires would achieve a compound amplitude quickly reaching the intolerable limit for both driver and vehicle. The Group A and C, on the contrary, would transmit a higher initial "jerk" force but would require a considerably greater number of closely spaced impacts before an intolerable compound reaction resulted.

As the Group A and C tires became severely worn and the directional tread elements were significantly reduced, the operator's subjective "ride" experience improved, whereas the Group B tires reacted essentially without change throughout the test.

TEST RESULTS

Figure 1 indicates the maximum traction developed by the two groups tested at each inflation pressure under investigation. Also shown on this graph at two inflation pressures is a profile of tire penetration in the test track. From these profiles the portion of the tread surface providing the most aggressive traction is apparent.

Figure 2 illustrates the complete Group A traction curve for each inflation pressure tested.

Figure 3 illustrates the complete Group F traction curve for each inflation pressure tested.

TEST PROGRAM

Test Course

A test course area was selected to provide high natural compaction affording minimal tire penetration and low coefficient of friction (.17-.25) when wet. The character of this course may be compared with wet grass matted slopes.

Separate test courses were constructed and used each day of test operation. Each test course was approximately 65 feet in length and 20 feet in width.

Test Vehicle and Dynamometer Unit

A Model "C" Tournapull was used as the "test bed" unit and an M-34 2 1/2 ton 6x6 vehicle, fully instrumented for this study, was used as the dynamometer unit.

Test Procedure

With the "test bed" vehicle attached to the Emery Load Cell System installed in the dynamometer unit the two vehicles, "test bed" vehicle leading, moved down the test course approach apron and stabilized at test speed with essentially zero pounds tractive force before entering the mud pit. After the "test bed" vehicle had entered the mud pit, the dynamometer vehicle slowly applied a resisting force inducing "test bed" wheel slip until zero forward motion or vehicle stall condition was achieved although the wheel speed of the "test bed" vehicle was maintained constant. Ground speed was recorded by means of a fifth wheel instrumented with a Weston DC tachometer generator. Two signals being produced simultaneously (pounds drawbar force and ground speed) were integrated and plotted by means of HTI function plotting recorder. This provided a recording of the complete traction curve for each run. An average of six runs was made at each inflation pressure for each group tested.

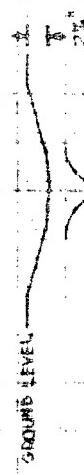
DYNAMIC TRACTION STUDY IN SHALLOW MUD

PROJECT 20-1-HO

MAXIMUM TRACTION GROUPS A & F

FIGURE 1

PROFILE OF TIRE PENETRATION



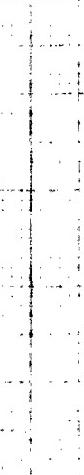
PROFILE OF TIRE PENETRATION



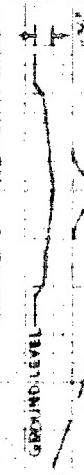
PROFILE OF TIRE PENETRATION



PROFILE OF TIRE PENETRATION



PROFILE OF TIRE PENETRATION



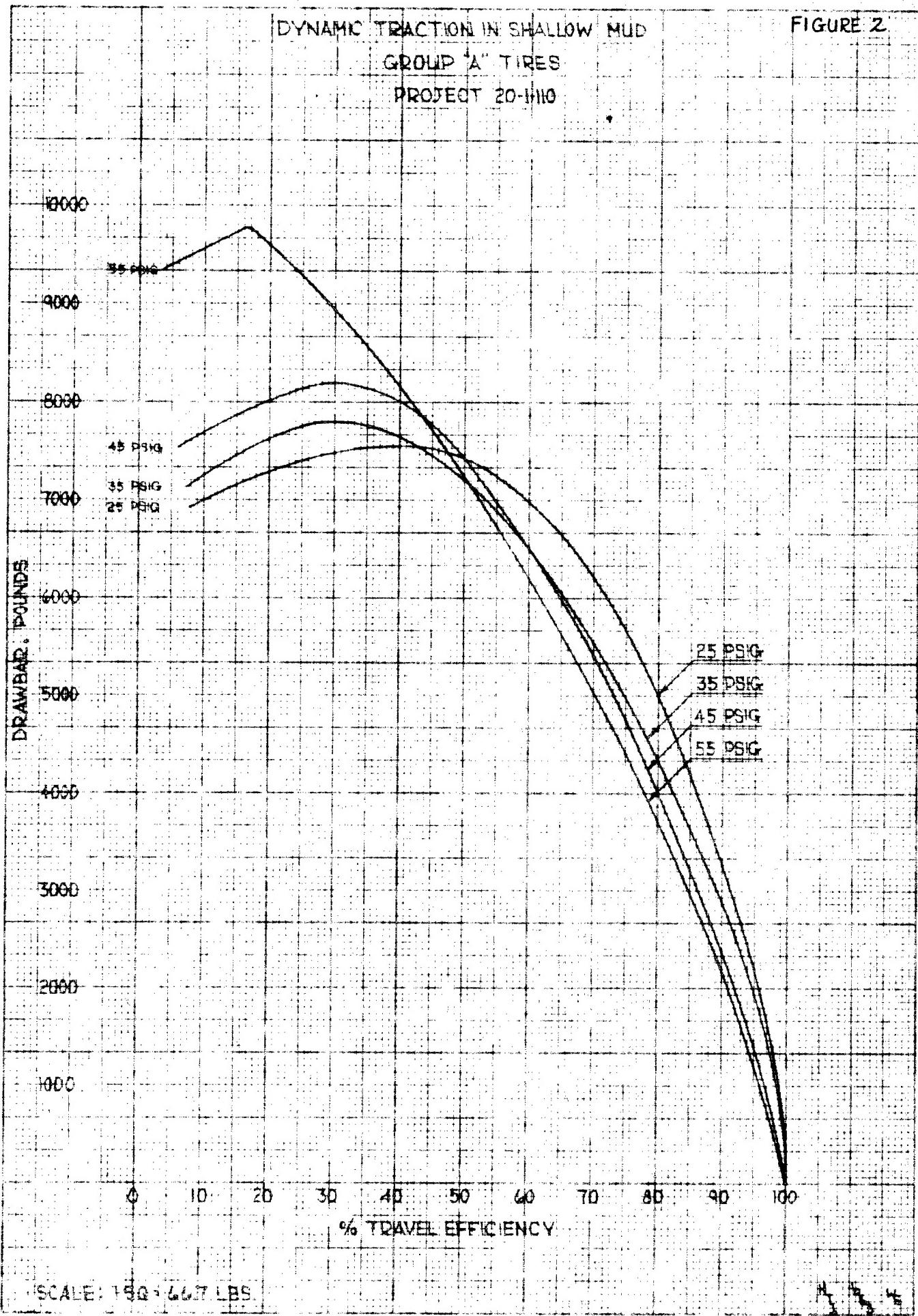
LEGEND

● GROUP A - FIRESTONE SUPER GROUND GRID GOER M.D. DIRECTIONAL (CONTROL)

✖ GROUP F - U.S. TACTICAL M.S. DADAL M.Y. CONSTRUCTION NON-DIRECTIONAL

DYNAMIC TRACTION IN SHALLOW MUD
GROUP "A" TIRES
PROJECT 20-1110

FIGURE 2

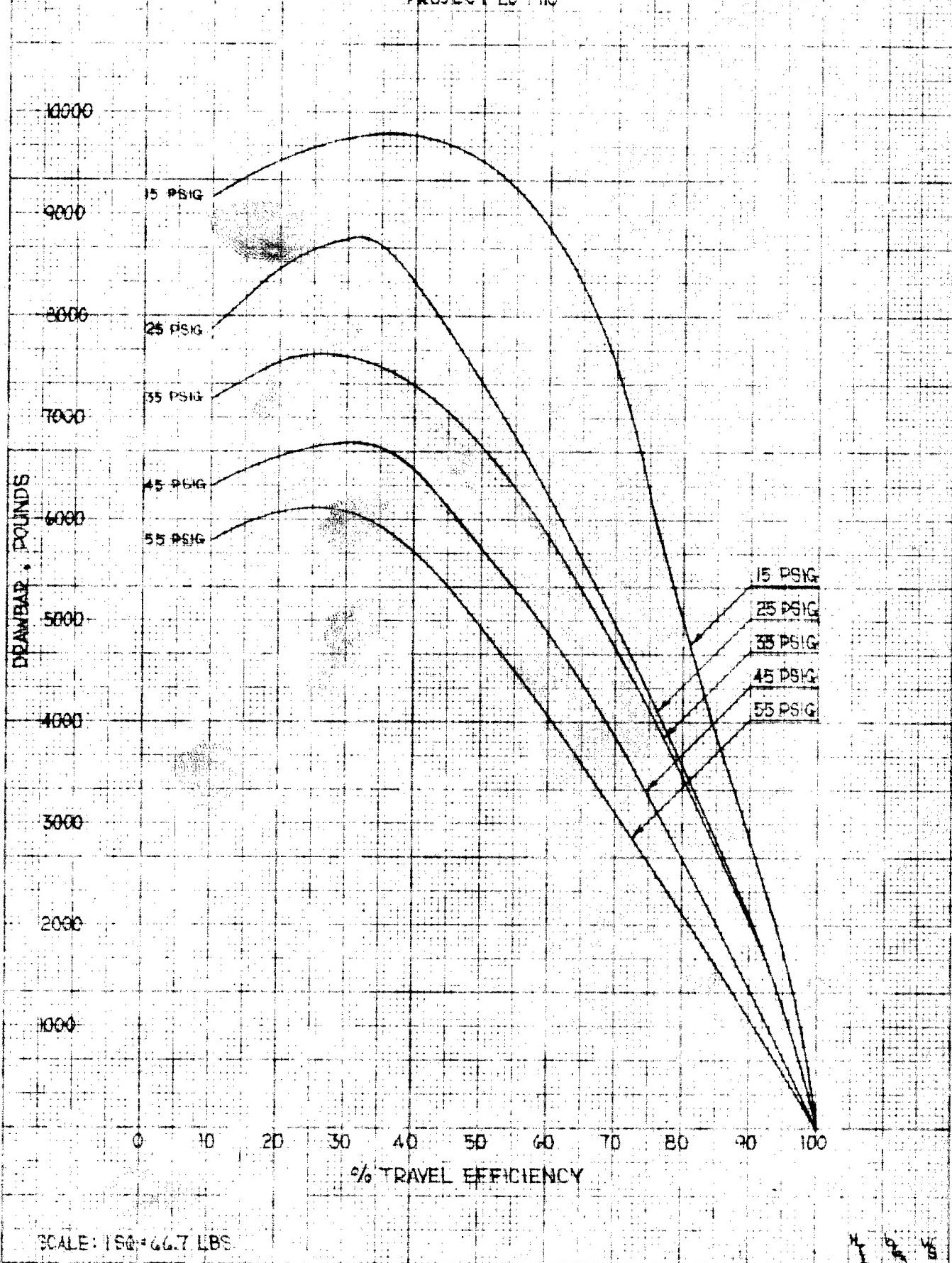


DYNAMIC TRACTION IN SHALLOW MUD

FIGURE 3

GROUP "F" TIRES

PROJECT 20-1-10



DEEP MUD TEST

Discussion

A specially constructed pit was required in which the depth of mud was 12 inches, the length of the pit was 220 feet and the width 40 feet. The consistency of the mud was maintained to a state wherein the vehicle would become immobile before the 220 feet distance was reached. The evaluation of one tire versus the other was made on the basis of distance traveled versus time. The vehicle remained in the same transmission gear throughout all tests, and when it became immobile the tires would spin out and not stall out. The test bed vehicle was such that only the front drive axle could be used; therefore, throughout all tests the rear axle was non-driving and the same set of tires remained on the rear axle throughout all tests. Experiments were conducted in respect to what effect inflation would have, and since there was no effect, all tests were conducted at a standard setting of 40 psi per tire. The depth of mud was determined to be the maximum allowable depth without high centering the vehicle. Inasmuch as no torque was transmitted to the rear axle, it was observed throughout each test that these tires would slide and in turn build up a large quantity of mud directly in front of each wheel. By the resistance created at this point, it increased the drag on the vehicle and in turn the front driving tires were called upon to do more work than would be expected if both axles were driving. Therefore, these tests are only a comparative type test of the three experimental groups as compared with the control group. By reviewing the attached data it will be noticed that the control tires, along with the experimental tires, have operated through the pit a total of three runs each, alternating from the control to the experimental, etc. After each run, the pit was floated down with a leveling device.

Due to a test bed vehicle breakdown, we were unable to compare the Ground Grip Directional Grooved Lugs.

TEST RESULTS:

FIRESTONE GROUND GRIP DIRECTIONAL DESIGN

(Control)

	<u>Time</u>	<u>Distance</u>	<u>Rating</u>
1.	41 Sec.	98' 10"	
3.	42 Sec.	101' 3"	
5.	<u>43 Sec.</u>	<u>94' 10"</u>	
Total..	126 Sec.	294' 11"	
Average..	42 Sec.	98' 3"	100

SUPER GROUND GRIP GOER

	<u>Time</u>	<u>Distance</u>	<u>Rating</u>
2.	91 Sec.	177' 10"	
4.	82 Sec.	165' 9"	
6.	<u>79 Sec.</u>	<u>161' 1"</u>	
Total..	252 Sec.	504' 8"	
Average..	74 Sec.	168' 2"	171

FIRESTONE GROUND GRIP DIRECTIONAL DESIGN

(Control)

	<u>Time</u>	<u>Distance</u>	<u>Rating</u>
1.	54.5 Sec.	86' 9"	
3.	58 Sec.	86' 1"	
5.	<u>54.5 Sec.</u>	<u>85' 1"</u>	
Total..	167 Sec.	257' 11"	
Average..	55.6 Sec.	85' 11"	100

ND-CC GOER

	<u>Time</u>	<u>Distance</u>	<u>Rating</u>
2.	26 Sec.	48' 3"	
4.	24 Sec.	47' 3"	
6.	<u>26 Sec.</u>	<u>48' 7"</u>	
Total...	76 Sec.	144' 1"	
Average...	25.3 Sec.	48'	56

APPENDIX

I. Abbreviations and Symbols	p i
II. Glossary of Trade Names	p ii
III. Deflection Sheets	p iii

APPENDIX I

ABBREVIATIONS AND SYMBOLS

°C	Degrees Centigrade
°F	Degrees Fahrenheit
FR-S	Firestone Rubber - Synthetic (styrene-butadiene type)
in	Inches
lb	Pounds
NR	Natural Rubber
psi	Pounds per square inch

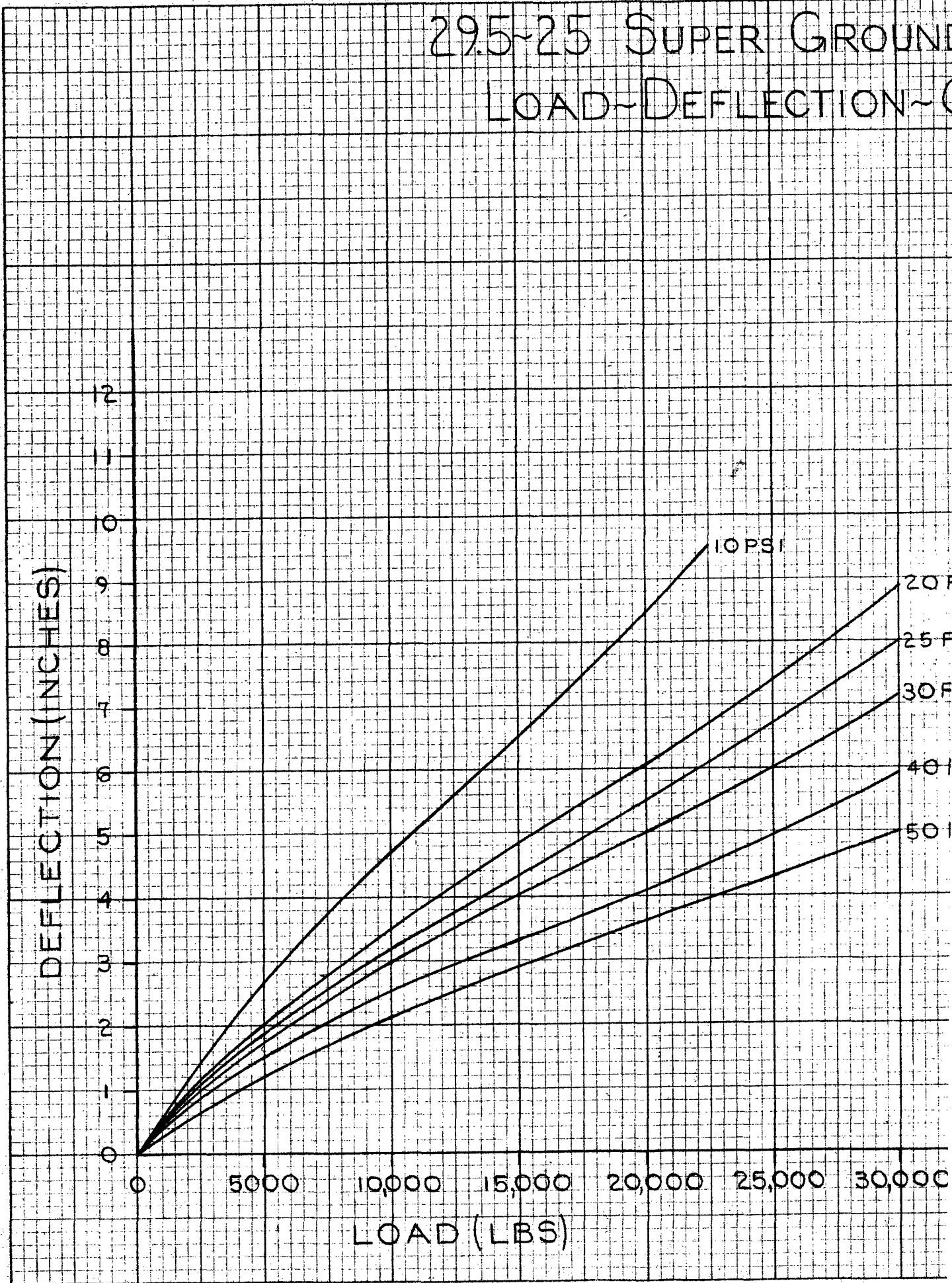
APPENDIX II

GLOSSARY OF TRADE NAMES

<u>TRADEMARK OR DESIGNATION</u>	<u>COMPOSITION</u>	<u>USE</u>	<u>SOURCE</u>
Isoprene	polyisoprene	Elastomer	Shell Chemical
Diene	polybutadiene	Elastomer	Firestone Tire & Rubber Co.
FR-S 123	butadiene-styrene copolymer oil masterbatch-31 phR oil	Elastomer	Firestone Tire & Rubber Co.
Hypalon	chlorosulfonated polyethylene	Elastomer	duPont
Neoprene	polychloroprene	Elastomer	duPont

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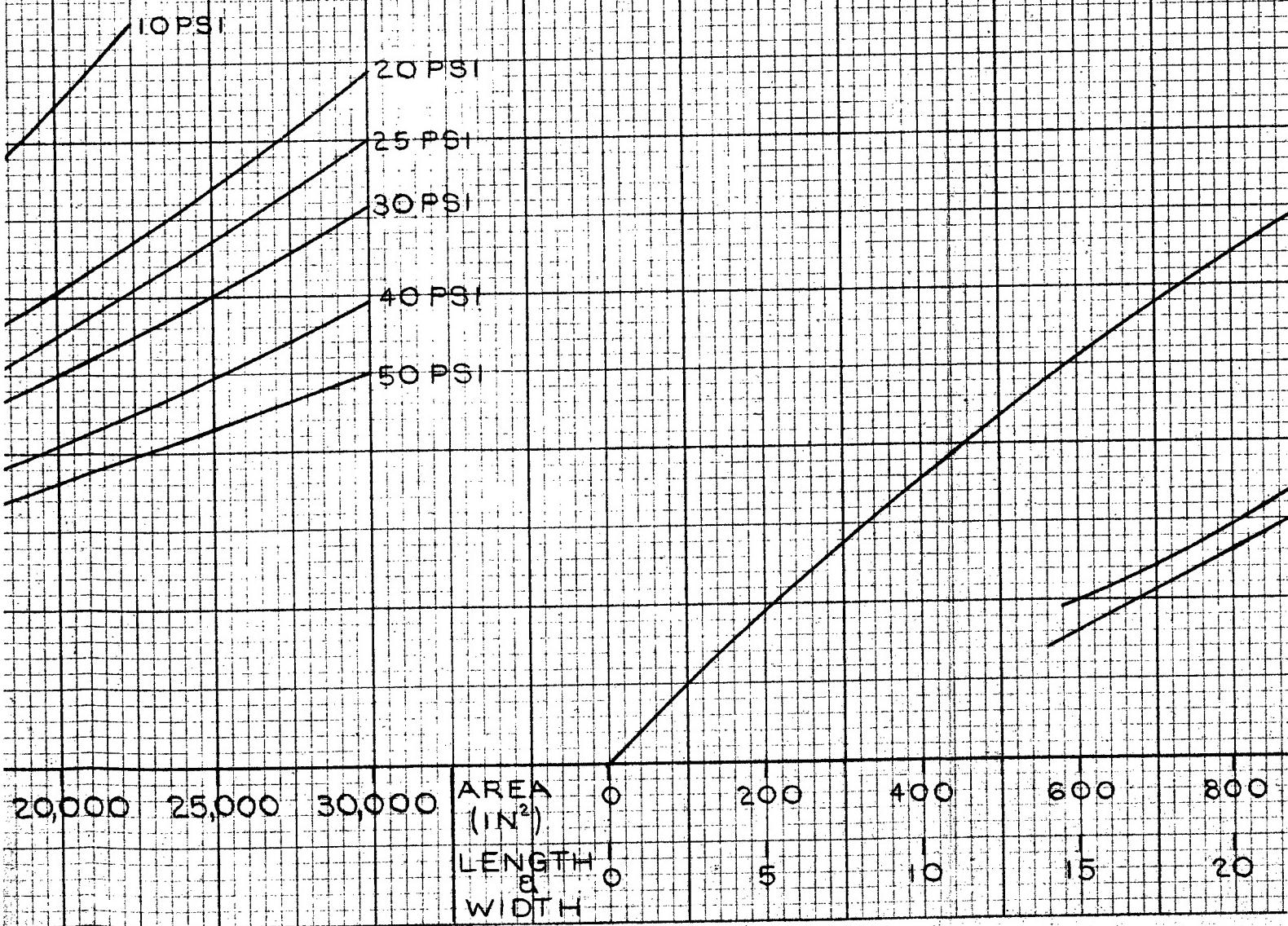
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LOAD~DEFLECTION~(



(2)

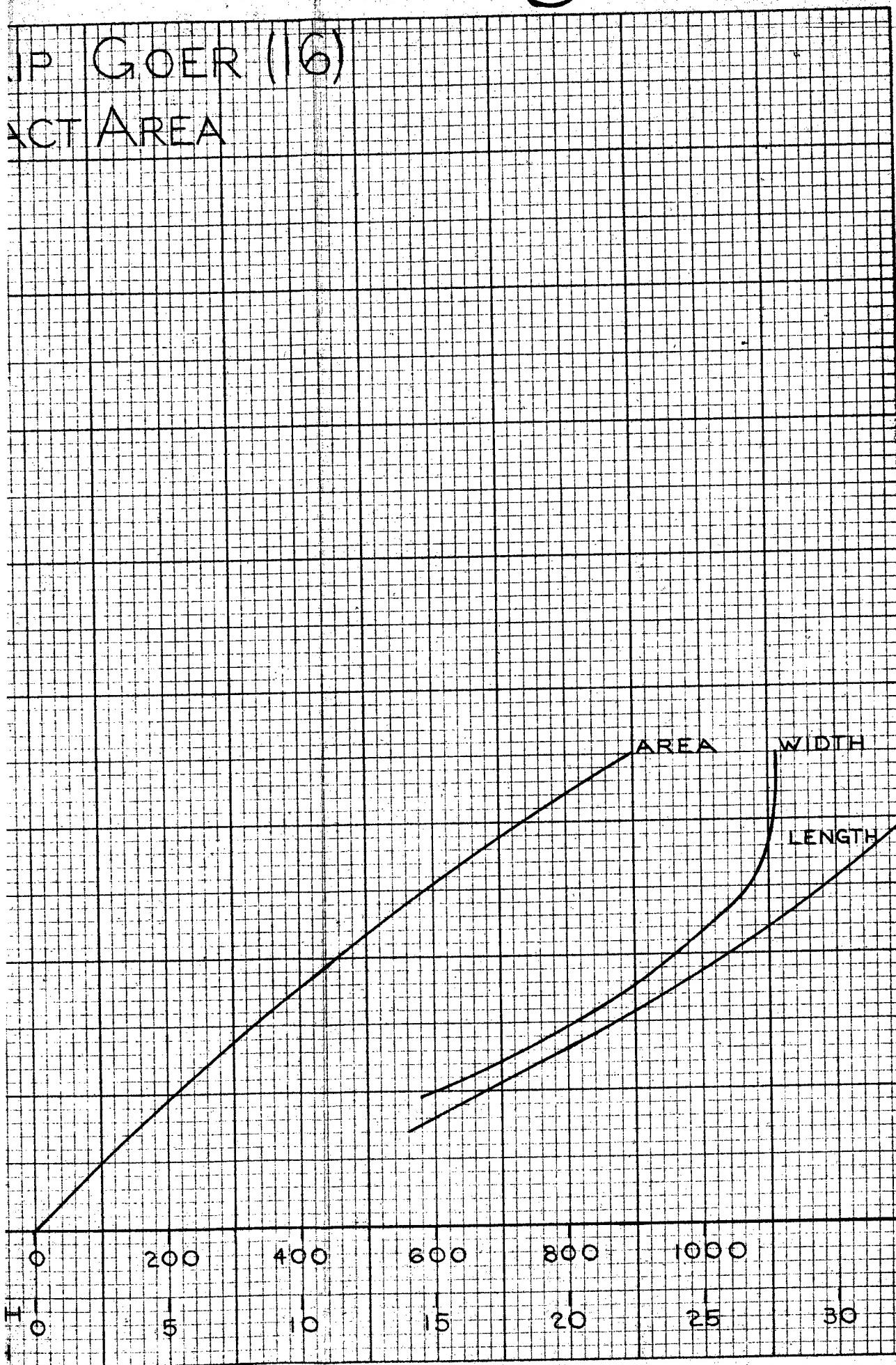
SUPER GROUND GRIP GOER (16)

~DEFLECTION~CONTACT AREA



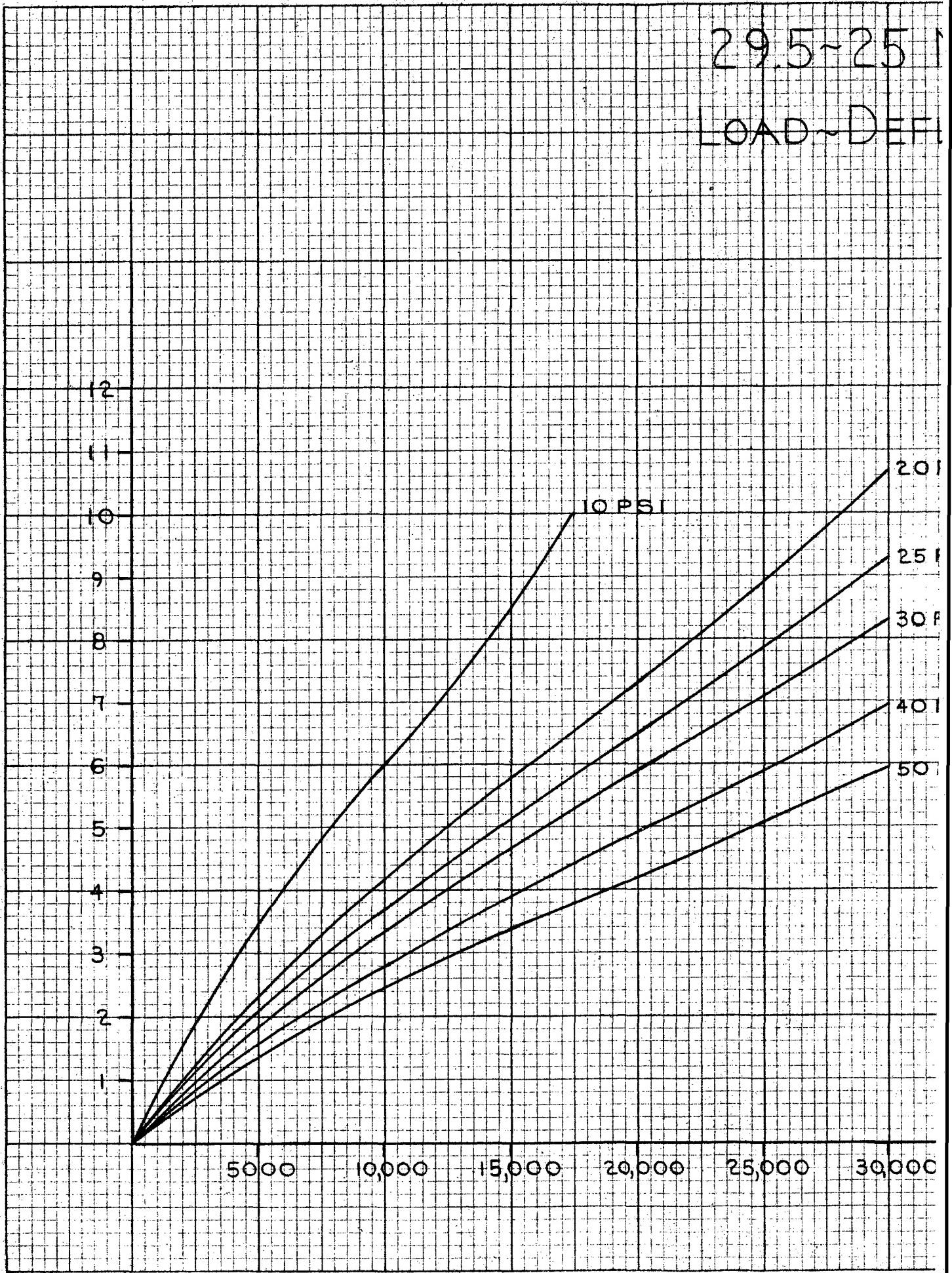
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P GOER (6)
ACT AREA



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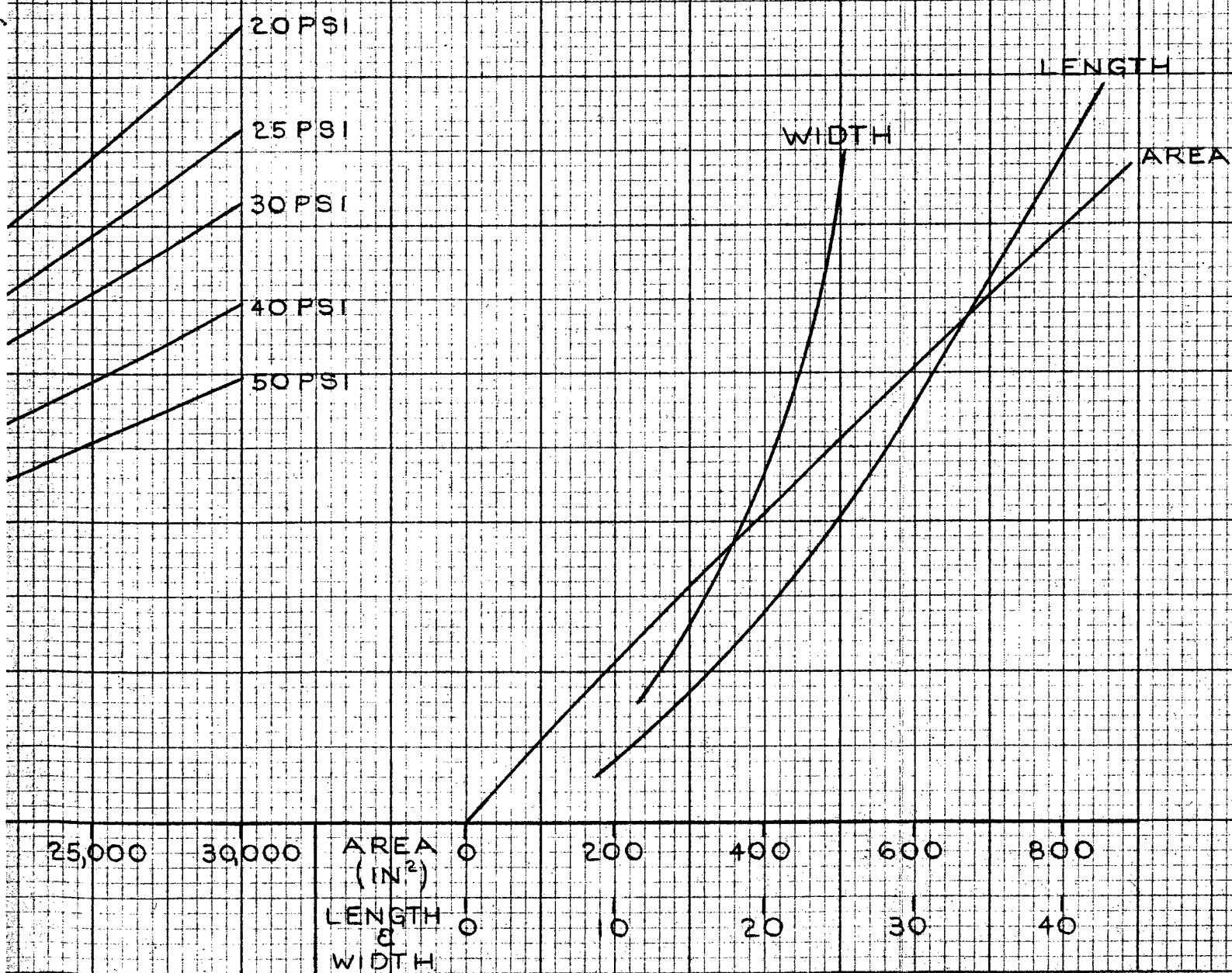
29.5~25
LOAD~DEF



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29.5-25 ND-CC GOER (6)

LOAD~DEFLECTION~CONTACT AREA



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ER (16)
TRACT AREA

LENGTH

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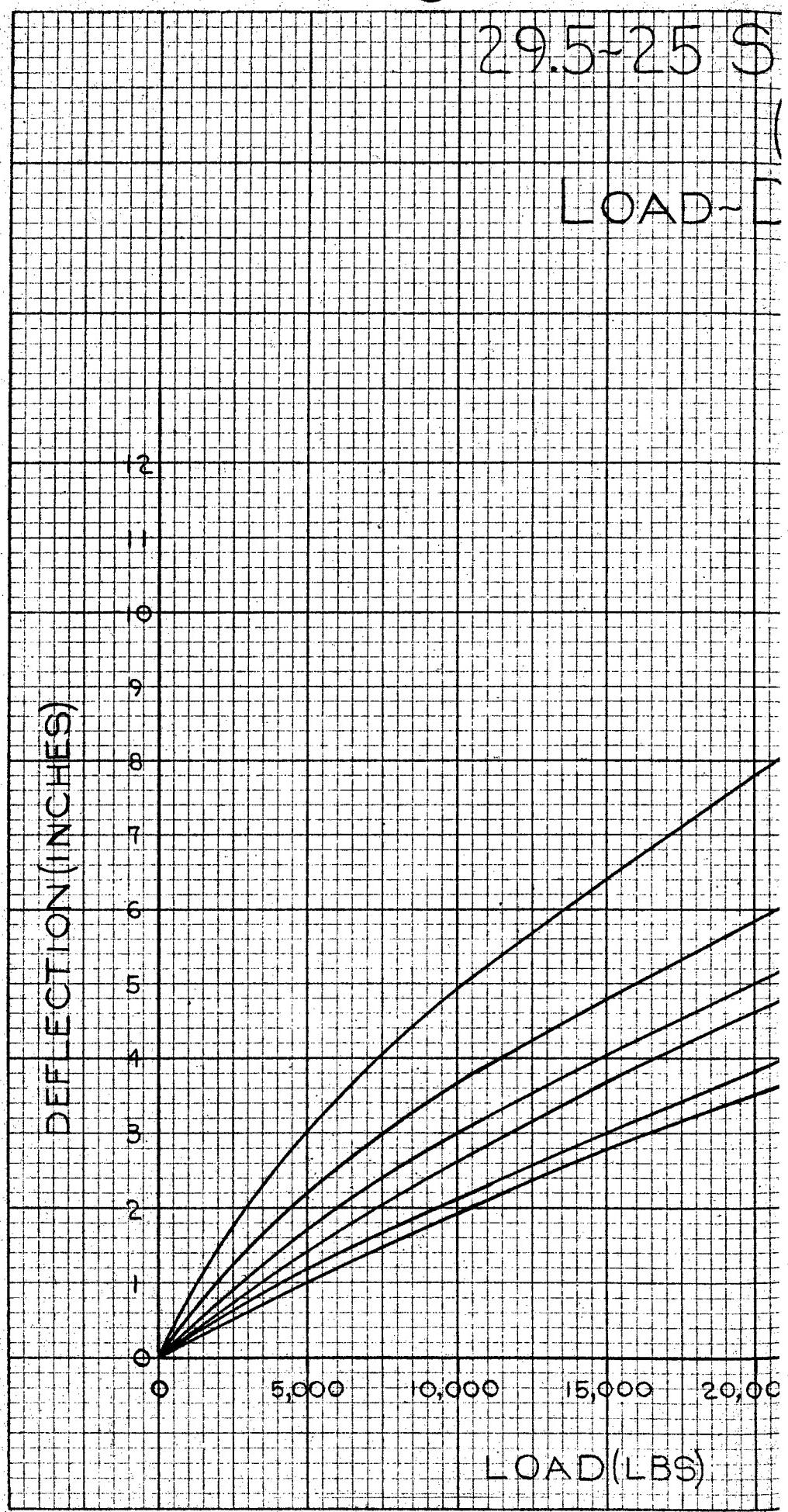
AREA

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20	30	40

(1)

29.5-25 S

LOAD -

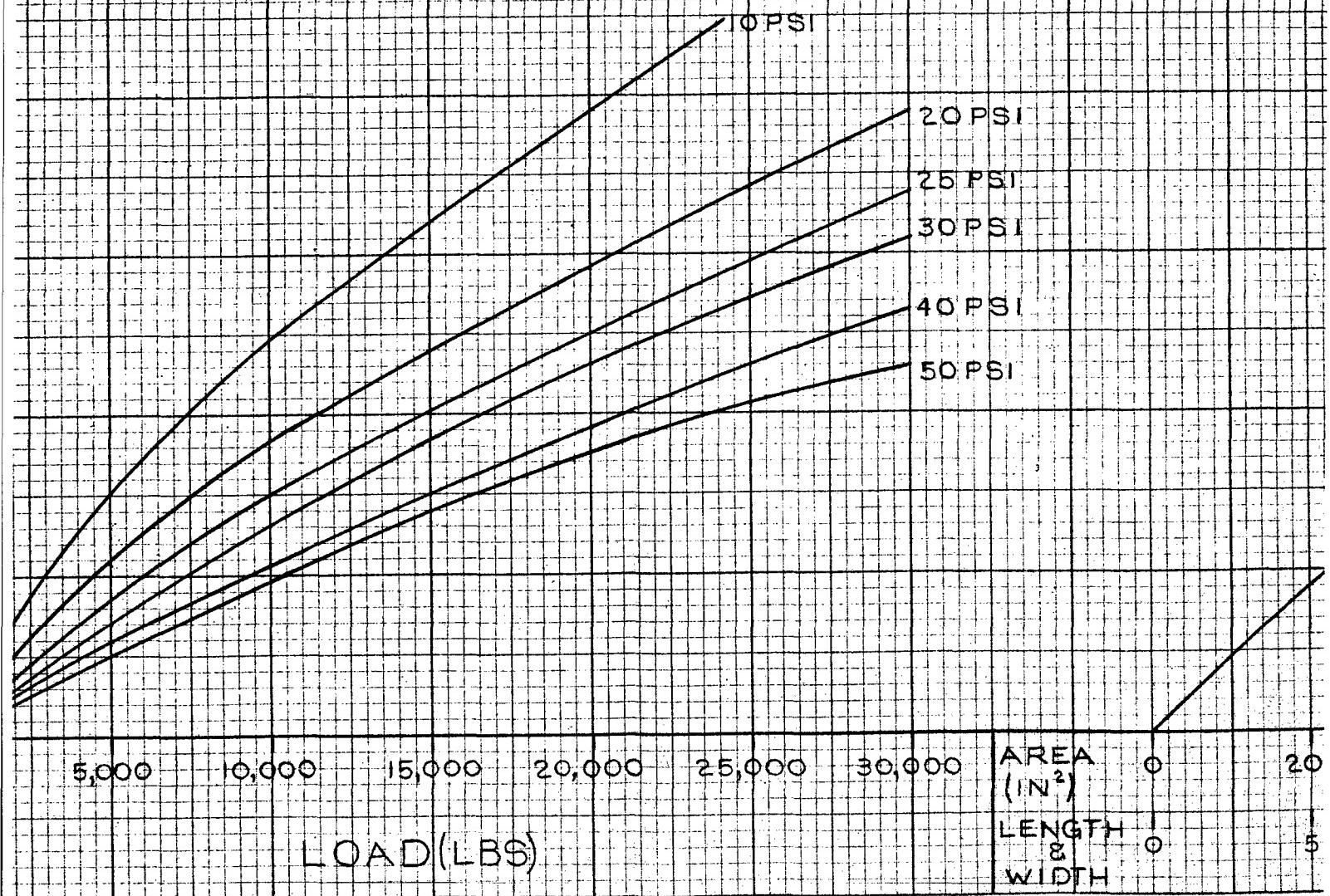


K-E 10 X 10 TO THE INCH 35F TLG
KEUFFEL & ESSER CO. NEW YORK

(2)

29.5-25 SUPER GROUND GRIP GC (WITH GROOVES)

LOAD ~ DEFLECTION ~ CONTACT

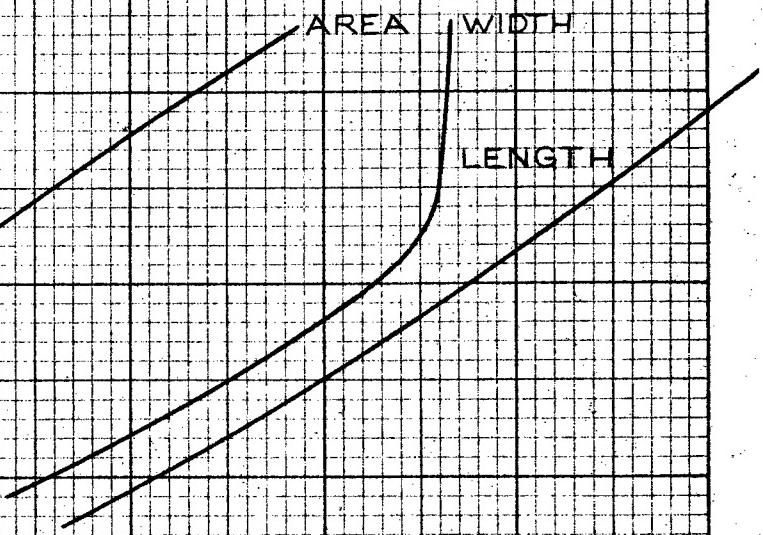


(3)

UND GRIP GOER(6)
COVES)
N~CONTACT AREA

20 PSI
25 PSI
30 PSI
40 PSI
50 PSI

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00	LENGTH & WIDTH	0	5	10	15	20	25



UNCLASSIFIED

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Q200X

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13. ABSTRACT

Earthmoving tires were specifically developed for use on the GOER vehicle. This development work included the design of various tread configurations and use of maximum feasible synthetic content. Tires were produced in three different tread designs, and two different levels of synthetic content. These tires were then tested for running temperature, traction, and mobility. Durability tests of 40% highway, 40% secondary roads, and 20% cross country were conducted. These tests showed that tires could be produced to provide at least 15,000 miles without any premature failures for this type of service.

These tires are more suited to the requirements of the GOER Vehicle than any commercially available tire. The major areas of improvement includes the capacity for continuous highway operation and improved performance in mud.

DD FORM 1 NOV 68 1473

REPLACES DD FORM 1473, 1 JAN 64, WHICH IS
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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Rubber Tires Synthetic Rubber Tubeless Tires Non-Destructive Testing Traction Testing Highway Operation Tire Tread Designs Off-Road Mobility						

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